Conservation Genetics and Captive Breeding

Peter Dratch, NPS & Tim King, USGS

Channel Island Fox
(*Urocyon littoralis*)

Captive Breeding of Channel Island Fox

Robert Wayne and Melissa Gray
UCLA Conservation Genetics Resource Center

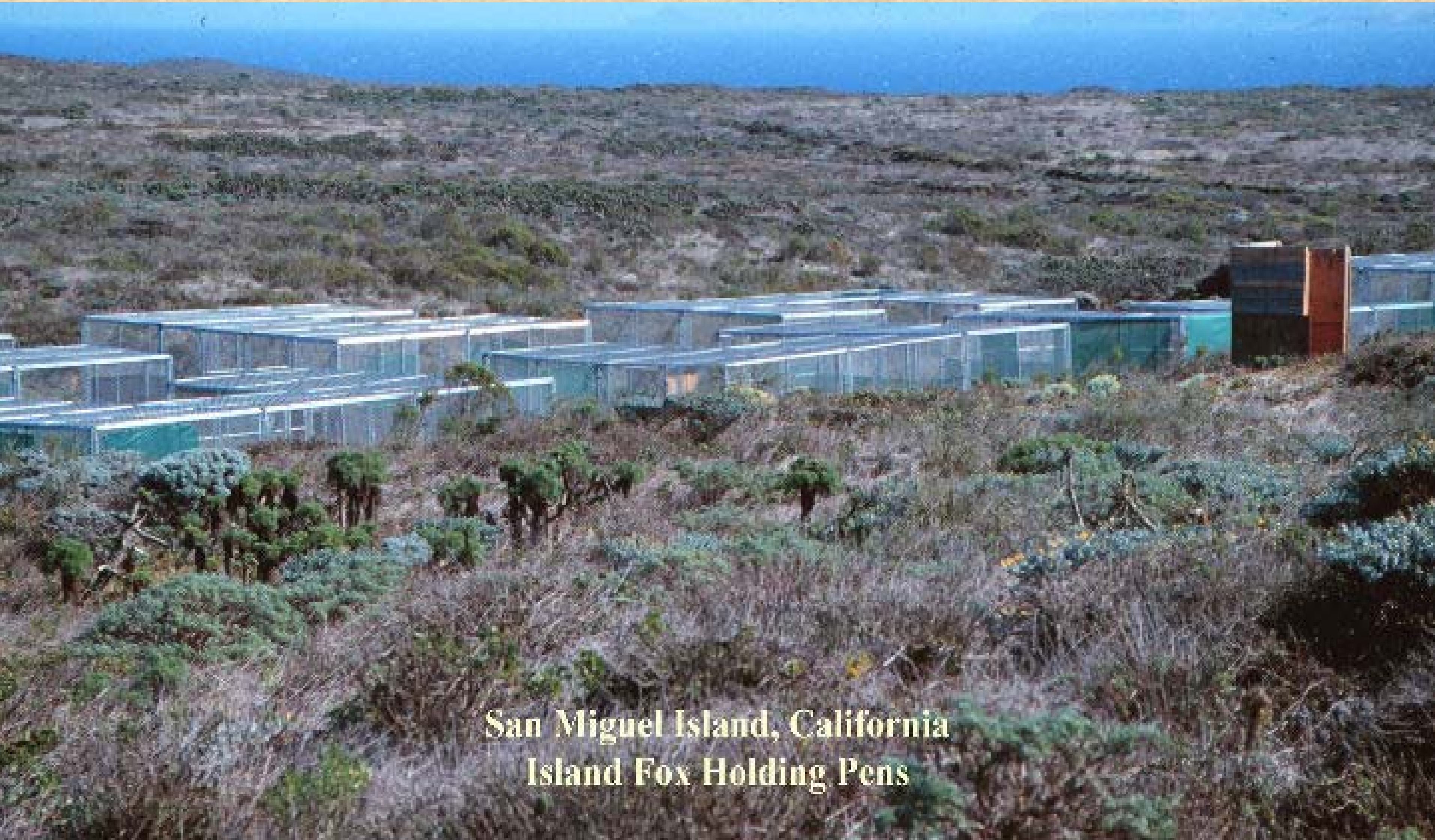
Coleen Lynch
AZA Population Management Center

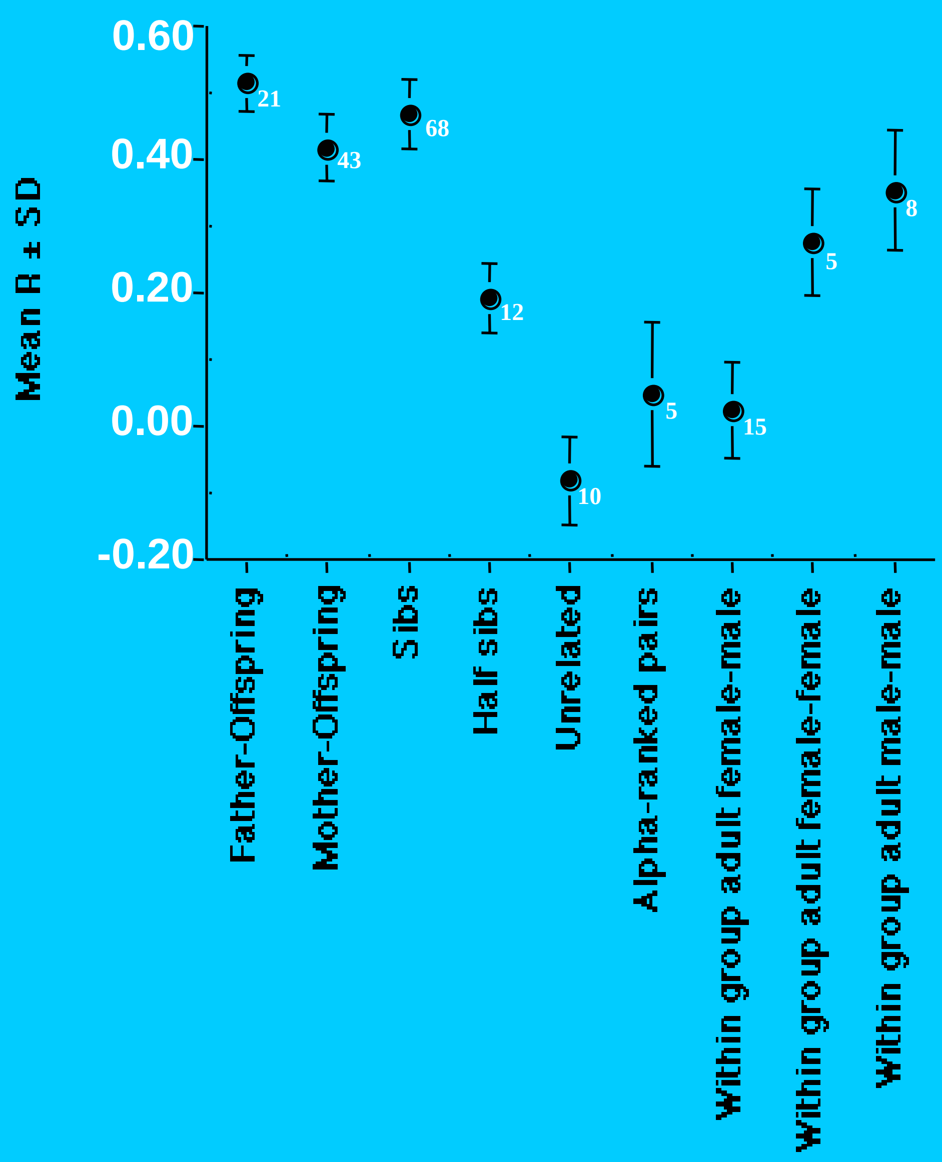
Tim Coonan
Channel Islands National Park

Genetic Management

A) Which individuals should be bred and paired?

B) Which individuals should be reintroduced?





Social Grouping

Relatedness of Adults

San Miguel

	Sex	M	F	M	F	F	F	M
Sex	**Individual**	**44829**	**90D1A**	**47B06**	**11929**	**60921**	**E2677**	**85D02**
M	**44829**	*						
F	**90D1A**	-0.070	*					
M	**47B06**	0.160	0.425	*				
F	**11929**	0.750	0.245	-0.069	*			
F	**60921**	-0.640	-0.189	-0.405	-0.371	*		
F	**E2677**	-0.191	0.478	0.058	0.134	0.400	*	
M	**85D02**	0.505	-0.059	-0.066	0.509	-0.197	-0.217	*
F	**92C32**	0.736	0.172	0.375	0.467	-0.467	0.077	0.042
F	**7534A**	-0.859	0.117	-0.145	-0.587	0.804	0.013	-0.190
F	**F6558**	-0.135	-0.514	-0.772	-0.120	0.374	0.111	0.192
M	**7574A**	-0.514	-0.086	0.525	-0.743	0.233	-0.181	-0.516
M	**57150**	0.481	0.040	-0.541	0.748	-0.162	0.125	0.699
F	**71071**	-0.181	0.597	0.411	-0.167	-0.306	0.425	0.004
F	**B0B25**	0.167	-0.302	-0.244	0.176	0.289	0.028	0.386
F	**92804**	-0.098	-0.527	0.386	-0.697	0.022	-0.273	-0.198
F	**61B03**	-0.493	-0.299	0.108	-0.758	0.459	-0.103	-0.395

SM r-values < -0.12

SR r-values < 0.08

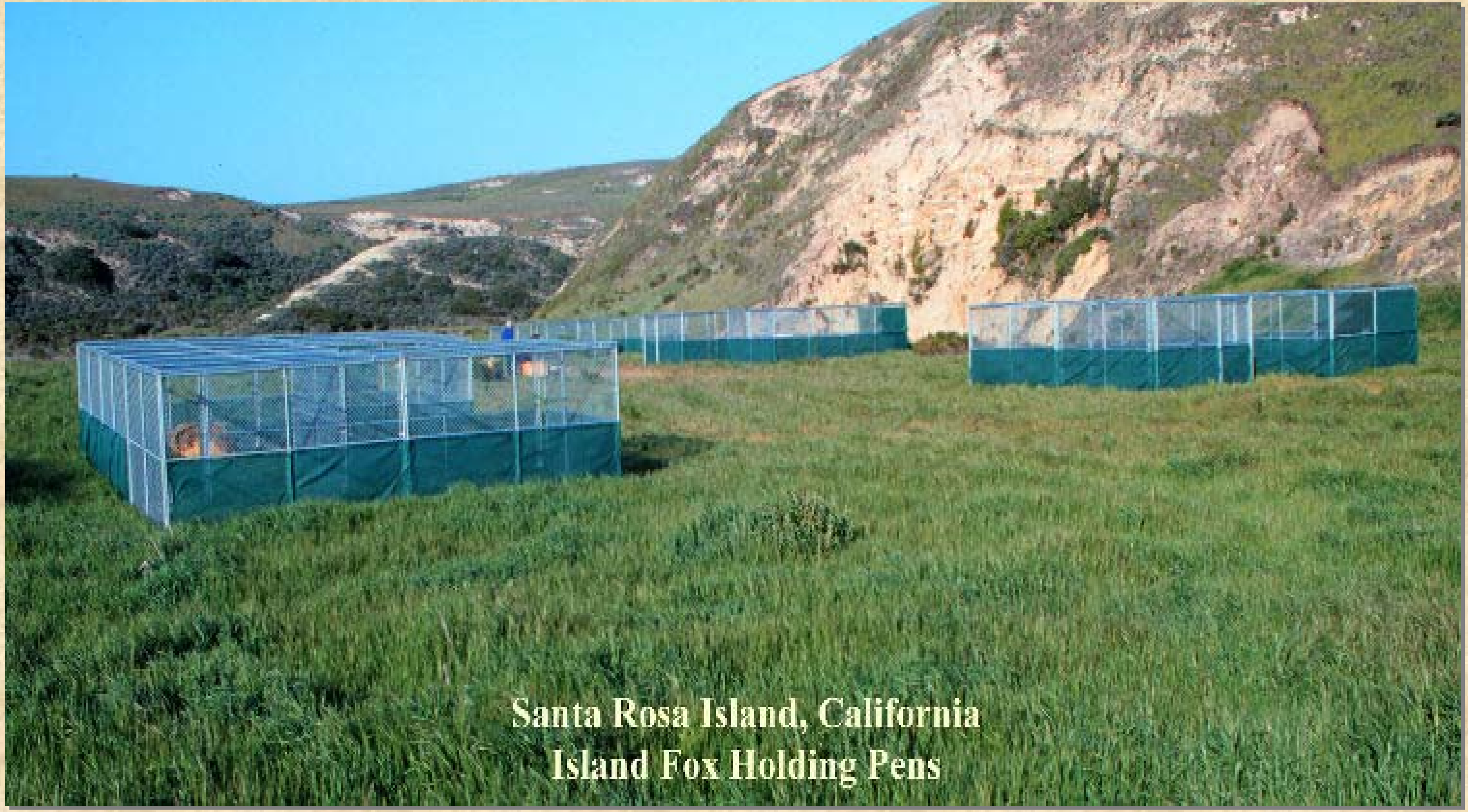
Relatedness of San Miguel pups

San Miguel		Pups (M)			
		Parents of pups			
Potential mates		C4A16/C7303		70C1D/83C24/11F73	
Sex	**ID**	**92C32 (F)**	**7574A (M)**	**90D1A (F)**	**44829 (M)**
M	44829	0.736	-0.514	-0.070	*
F	90D1A	0.172	-0.086	*	-0.070
M	47B06	0.375	0.525	0.425	0.160
F	11929	0.467	-0.743	0.245	0.750
F	**60921**	-0.467	0.233	**-0.189**	**-0.640**
F	**E2677**	**0.077**	**-0.181**	0.478	-0.191
M	85D02	0.042	-0.516	-0.059	0.505
F	92C32	*	-0.349	0.172	0.736
F	7534A	-0.668	0.436	0.117	-0.859
F	**F6558**	**-0.217**	**-0.421**	**-0.514**	**-0.135**
M	**7574A**	-0.349	*	**-0.086**	**-0.514**
M	57150	0.184	-1.024	0.040	0.481
F	**71071**	**-0.256**	**0.071**	0.597	-0.181
F	B0B25	0.114	-0.488	-0.302	0.167
F	**92804**	-0.179	0.550	**-0.527**	**-0.098**
F	**61B03**	-0.302	0.697	**-0.299**	**-0.493**

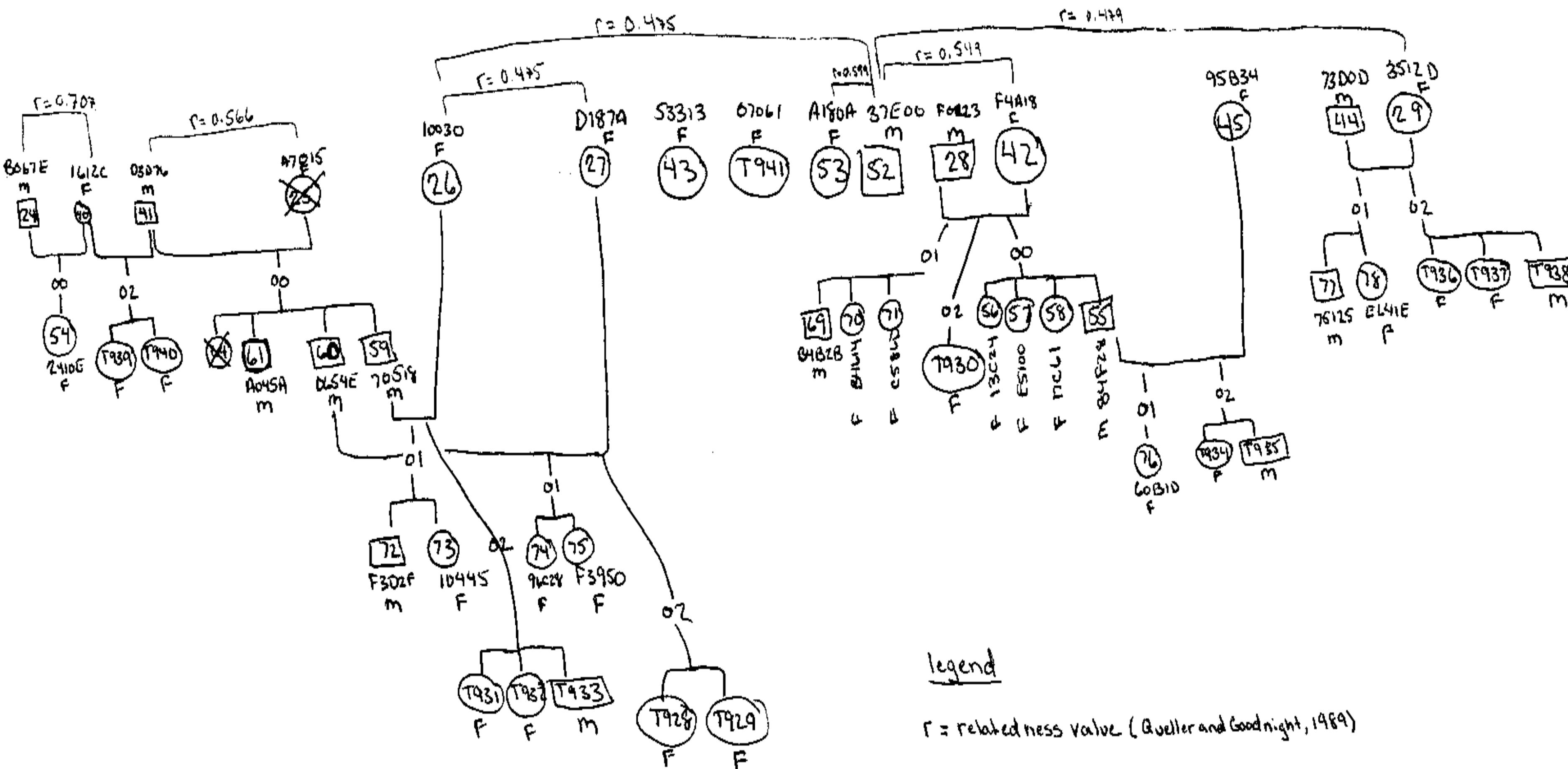
SM r-values < -0.12

Santa Rosa Island

2000: 14 individuals, all but 1 in captivity



Channel Island Fox Pedigree: Santa Rosa



legend

r = relatedness value (Queller and Goodnight, 1989)

O = females

□ = males

X = death

(#) = studbook number

(T#) = temporary studbook number

San Miguel		Ranking			
ID	sex	1ST	2ND	3RD	4TH
C7303	M	F6558	71071	E2677	
C4A16	M	F6558	71071	E2678	
70C1D	M	60921	92804		
		F6558			
		61B03			
83C24	M	60921	92804		
		F6558			
		61B03			
11F73	M	60921	92804		
		F6558			
		61B03			
85D02	M	61B03	92804		
		E2677	60921		
			7534A		
57150	M	61B03	7534A	71071	
		92804		60921	
47B06	M	F6558	60921	7534A	11929
			BOB25		
11929	F	47B06			
71071	F	57150	C7303		
			C4A16		
60921	F	47B06	70C1D	85D02	
			83C24	57150	
			11F73		
F6558	F	47B06	C7303	70C1D	
			C4A16	83C24	
				11F73	
7534A	F	57150	47B06		
			85D02		
BOB25	F	47B06			
92804	F	57150	85D02	70C1D	
				83C24	
				11F73	
E2677	F	85D02	C7303		
			C4A16		
			47B06		
61B03	F	57150	85D02		
			70C1D		
			83C24		
			11F73		

Suggested parings & reintroduction for San Miguel and Santa Rosa

Island Fox (*Urocyon littoralis*)

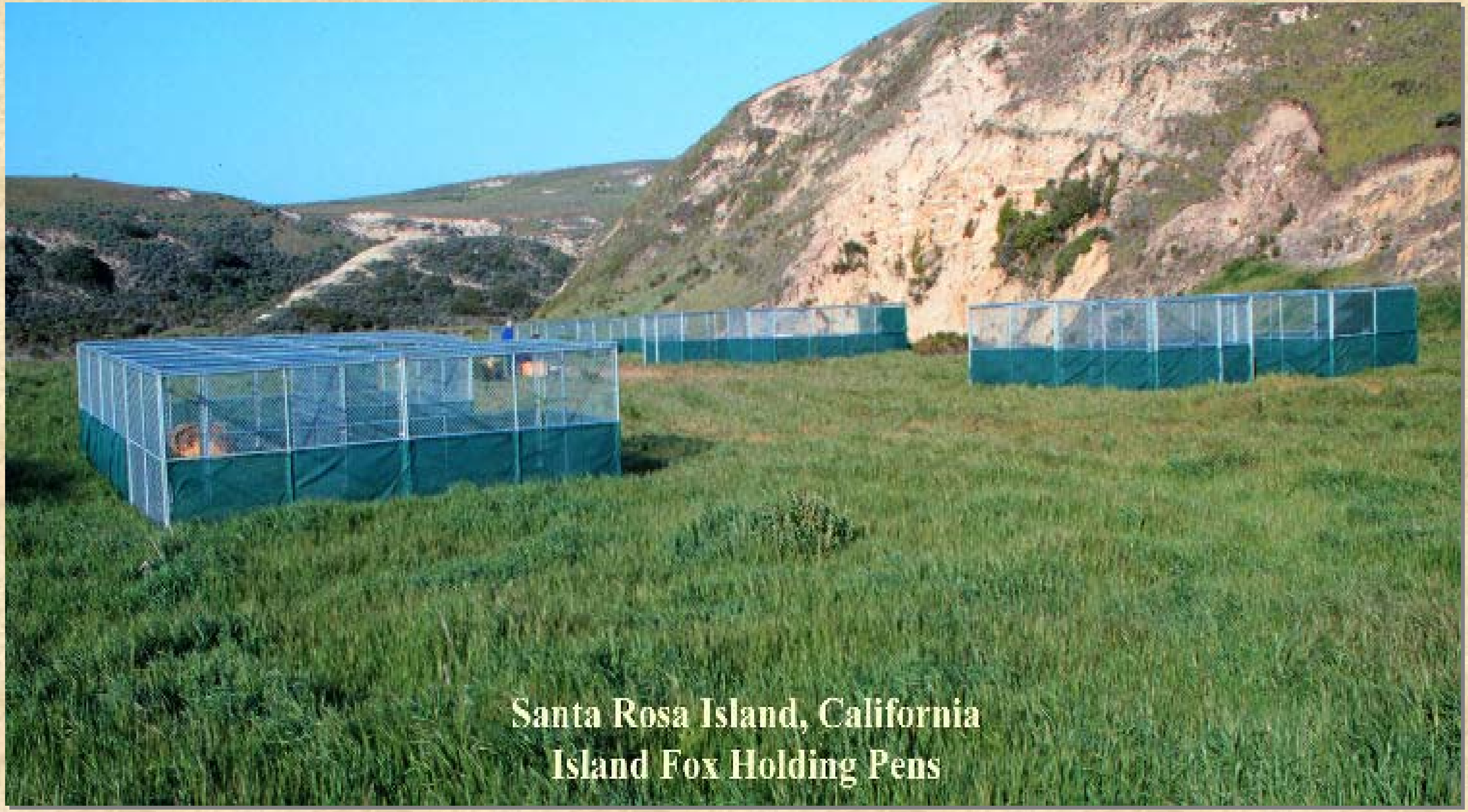
Santa Rosa		Ranking			
ID	sex	1ST	2ND	3RD	4TH
34614	F	D3D76	F3D2F		
		B067E			
C586D	F	D3D76	F3D2F		
		B067E			
B4B2B	M	2410E	10445		
		1612C			
10445	F	B4B2B	A045A		
F3D2M	M	E5100	34614		
			C586D		
96C2E	F	37E00	75125	B4B2B	
F3950	F	37E01	75126	B4B2B	
60B1D	F	A045A	75125	B067E	
75125	M	53313	60B1D		
E6D1E	F	A045A			
D3D76	M	E5100	37C61	13C24	
		34614	53313	A180A	
		C586D		1612C	
B067E	M	34614	53313	13C24	E5100
		C586D		A180A	
				37C61	
37E00	M	96C2E	1612C		
		F3950	2410E		
			53313		
			2410E		
A045A	M	53313	13C24	E5100	10445
		60B1D	A180A	37C61	
E5100	F	F3D2F	A045A	B067E	
		D3D76		75125	
2410E	F	B4B2B		37E00	
13C24	F	A045A	D3D76		
A180A	F	D3D76	A045A		
		B067E			
1612C	F	B4B2B	D3D76		
37C61	F	D3D76	B067E	A045A	
		F3D2F			
53313	F	F3D2F			
		75125			
		D3D76			
		B067E			
		A045A			

Santa Rosa Island

2000: 14 individuals, all but 1 in captivity

2004: 45 total, 16 males/ 29 females, first releases

2005: 73 total, at least half planned for release



Island Fox Rescue Depends Critically on Cooperation

NPS
FWS
NC
UCLA
UCDavis
USGS
CIC
AZA/
PMC
CFG
CESU

Captive Breeding Management
(Ex situ conservation)

The Robust
Unique Multilocus Genotype

USGS
science for a changing world

Captive Breeding Management

Captive Breeding Management Plan = Species Survival Plan

Plan must facilitate the maintenance of a genetically viable and demographically stable population of a species in captivity (95 % chance of survival for 100 years (Ballou)).

Establish a metapopulation structure (subpopulations in geographically distinct areas)

Prerequisites and Assumption

Prerequisites

Phylogeographic and phylogenetic relationships within and among close relatives is known

Sufficient genetic diversity to realize unique multilocus genotypes

Assumption

Preserving maximum levels of genetic diversity within and among populations will increase fitness

Captive Breeding Successes

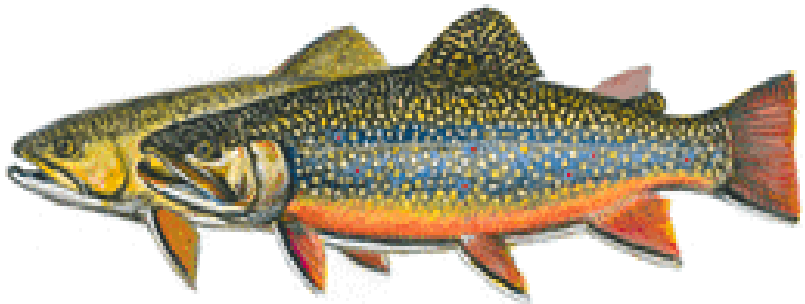
- 19% of all mammals, 10% of all bird species have been bred in captivity.
- 90% of all mammals, 74% of all birds added to U.S. zoo collections since 1985 were born in captivity.
- Some species are extinct in the wild but thrive in zoos: Przewalski's horse, Arabian Oryx, Pere David's deer.
- A number of wild populations of species were born in captivity and now live free: Bald Eagle, whooping crane, Andean condors, red wolves, Golden Lion Tamarin.
- A successful captive breeding program by USFWS with a bobwhite quail generated the creation of a wildlife refuge in southern Arizona to allow its successful reintroduction.
- Public awareness and concern can be mobilized by such efforts.

Unique Multilocus Genotypes

Sfo Loci

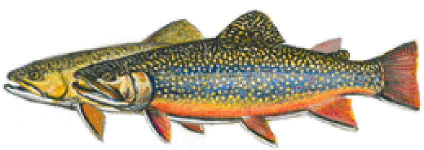
Fish ID	SfoB52		SfoC24		SfoC28		SfoC38		SfoC79		SfoC86		SfoC88		SfoC113		SfoC115		SfoC129		SfoD75		SfoD91		SfoD100	
MD7-18	187	215	116	119	175	183	140	146	123	123	113	116	178	187	139	139	333	341	221	233	208	208	212	240	226	230
MD7-19	201	225	158	158	183	199	143	143	123	123	101	110	181	193	139	157	365	365	227	233	200	212	240	240	214	230
MD7-20	201	215	116	122	175	191	143	146	120	123	110	116	181	187	136	139	341	365	233	233	200	204	212	216	238	250
MD7-21	215	225	110	113	175	183	140	146	123	123	113	122	178	193	139	151	333	337	230	233	212	216	212	244	226	234
MD7-22	225	225	113	119	175	199	143	146	120	123	113	116	181	187	130	157	337	365	227	230	208	216	212	240	214	238

Alleles measured in base pairs

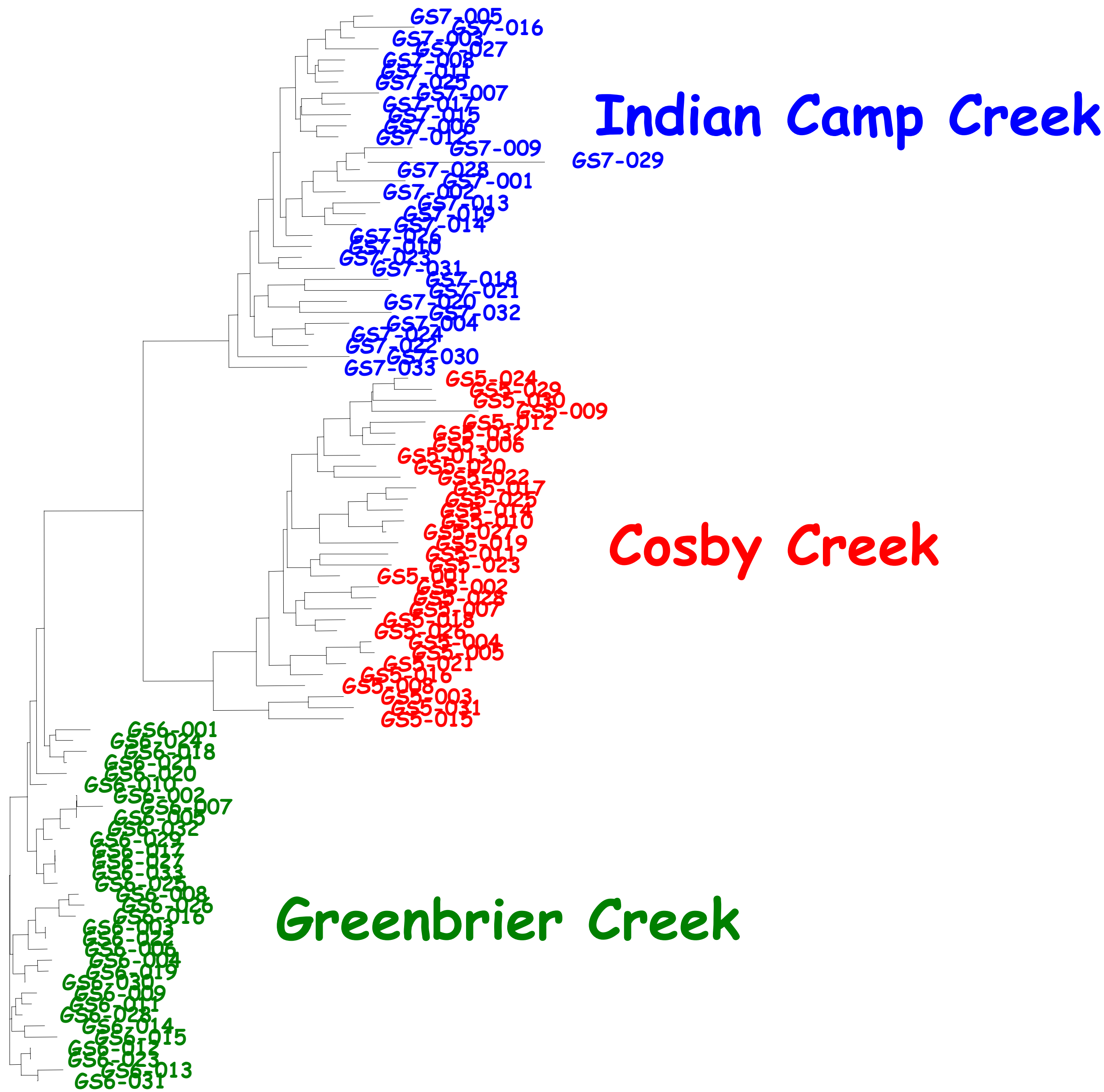


Brook trout - GRSM

Unique Multilocus Genotypes



Brook trout - GRSM



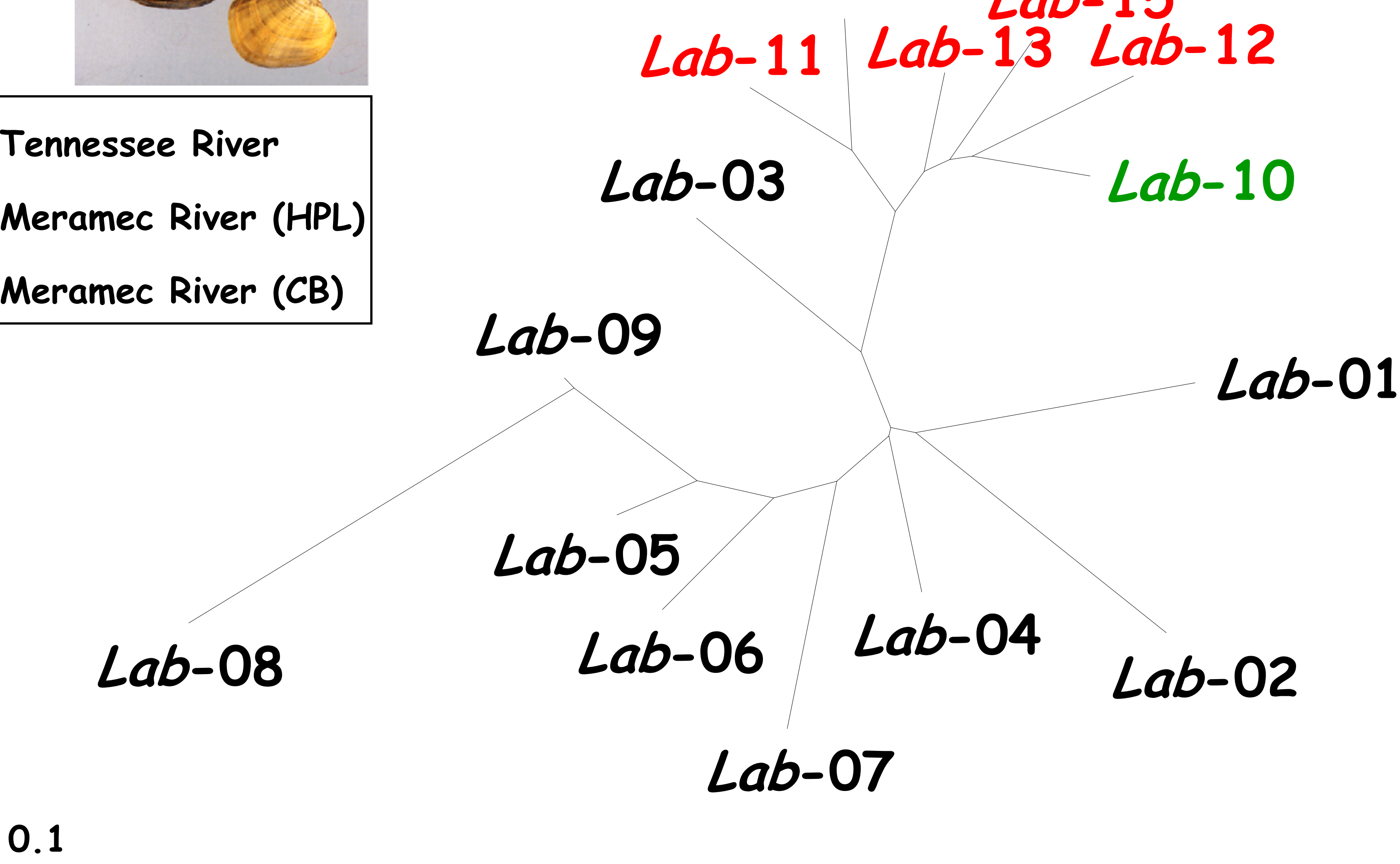
0.1

PSA
Units

Applications of
Unique Multilocus Genotypes

- Delineate fine-scale population structure
- Genetic Stock Identification
- Enhanced assignment or allocation analysis
- Hybridization
- Movement
- **Kinship**

Lampsilis abrupta - Genetic Distance among Individuals



Neighbor-Joining Tree - Proportion of Shared Alleles
Multilocus Genotypes from 15 Microsatellite DNA Loci

Enlightened Broodstock Management

The Connecticut River  Experiment

Assess baseline levels of genetic diversity and variation
- Determine multi-locus genotypes

Increase levels of heterozygosity
- Calculate genetic distance (PSA) between individuals
- Cross distantly related individuals to increase heterozygosity (and alter the distribution of alleles)

Result: heterozygosity increased 6.2% in one generation

Increase levels of genetic diversity
- Introduce new alleles from other populations (if necessary)

Proportion of Shared Alleles (PSA) Distance

Lampsilis abrupta

Lampsilis abrupta

Animal 1	Animal 2	PSA	Animal 1	Animal 2	PSA	Animal 1	Animal 2	PSA
Lab-011	Lab-014	0.836	Lab-005	Lab-015	1.792	Lab-002	Lab-011	2.303
Lab-010	Lab-015	0.916	Lab-006	Lab-007	1.792	Lab-003	Lab-005	2.303
Lab-013	Lab-015	0.916	Lab-006	Lab-009	1.792	Lab-003	Lab-008	2.303
Lab-010	Lab-012	1.003	Lab-006	Lab-015	1.792	Lab-003	Lab-012	2.303
Lab-010	Lab-013	1.003	Lab-009	Lab-011	1.792	Lab-006	Lab-011	2.303
Lab-011	Lab-013	1.003	Lab-011	Lab-012	1.792	Lab-007	Lab-014	2.303
Lab-012	Lab-013	1.003	Lab-014	Lab-015	1.792	Lab-007	Lab-015	2.303
Lab-013	Lab-014	1.099	Lab-001	Lab-002	2.015	Lab-009	Lab-015	2.303
Lab-005	Lab-006	1.204	Lab-001	Lab-005	2.015	Lab-001	Lab-003	2.708
Lab-011	Lab-015	1.204	Lab-001	Lab-006	2.015	Lab-001	Lab-010	2.708
Lab-012	Lab-015	1.204	Lab-001	Lab-007	2.015	Lab-002	Lab-007	2.708
Lab-012	Lab-014	1.322	Lab-001	Lab-015	2.015	Lab-002	Lab-010	2.708
Lab-003	Lab-004	1.455	Lab-002	Lab-005	2.015	Lab-002	Lab-012	2.708
Lab-005	Lab-009	1.455	Lab-002	Lab-009	2.015	Lab-002	Lab-013	2.708
Lab-008	Lab-009	1.455	Lab-002	Lab-014	2.015	Lab-004	Lab-011	2.708
Lab-010	Lab-011	1.455	Lab-003	Lab-006	2.015	Lab-005	Lab-013	2.708
Lab-010	Lab-014	1.455	Lab-003	Lab-009	2.015	Lab-005	Lab-014	2.708
Lab-001	Lab-004	1.609	Lab-003	Lab-011	2.015	Lab-006	Lab-012	2.708
Lab-001	Lab-011	1.609	Lab-003	Lab-014	2.015	Lab-006	Lab-013	2.708
Lab-003	Lab-007	1.609	Lab-004	Lab-008	2.015	Lab-006	Lab-014	2.708
Lab-003	Lab-010	1.609	Lab-004	Lab-009	2.015	Lab-007	Lab-008	2.708
Lab-003	Lab-013	1.609	Lab-004	Lab-012	2.015	Lab-009	Lab-010	2.708
Lab-004	Lab-006	1.609	Lab-004	Lab-013	2.015	Lab-009	Lab-014	2.708
Lab-004	Lab-007	1.609	Lab-004	Lab-014	2.015	Lab-001	Lab-012	3.401
Lab-004	Lab-015	1.609	Lab-005	Lab-012	2.015	Lab-002	Lab-015	3.401
Lab-005	Lab-007	1.609	Lab-006	Lab-008	2.015	Lab-005	Lab-011	3.401
Lab-005	Lab-008	1.609	Lab-006	Lab-010	2.015	Lab-007	Lab-010	3.401
Lab-007	Lab-009	1.609	Lab-007	Lab-011	2.015	Lab-007	Lab-013	3.401
Lab-002	Lab-003	1.792	Lab-007	Lab-012	2.015	Lab-008	Lab-011	3.401
Lab-002	Lab-004	1.792	Lab-009	Lab-013	2.015	Lab-008	Lab-012	3.401
Lab-002	Lab-008	1.792	Lab-001	Lab-008	2.303	Lab-008	Lab-013	3.401
Lab-003	Lab-015	1.792	Lab-001	Lab-009	2.303	Lab-008	Lab-014	3.401
Lab-004	Lab-005	1.792	Lab-001	Lab-013	2.303	Lab-009	Lab-012	3.401
Lab-004	Lab-010	1.792	Lab-001	Lab-014	2.303	Lab-008	Lab-010	10
Lab-005	Lab-010	1.792	Lab-002	Lab-006	2.303	Lab-008	Lab-015	10

The Connecticut River  Experiment

Gene marking - 2 for the price of 1; will determine levels of genetic variability and allow assessment of all aspects of the stocking program

Determine CR tributaries with the greatest production

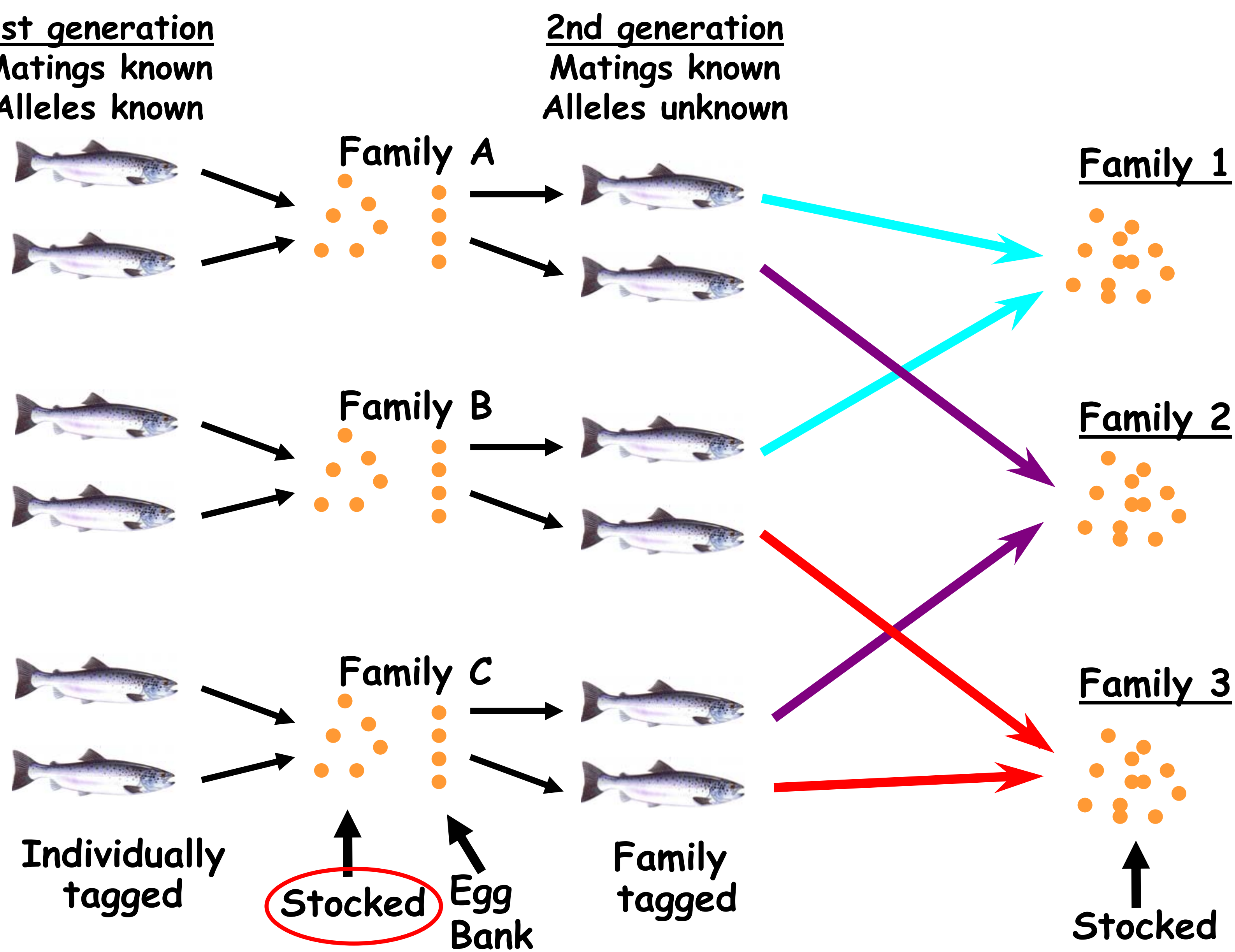
↓

Determine the favorable characteristics of productive tributaries

↓

Ultimately achieve restoration of a reproducing population

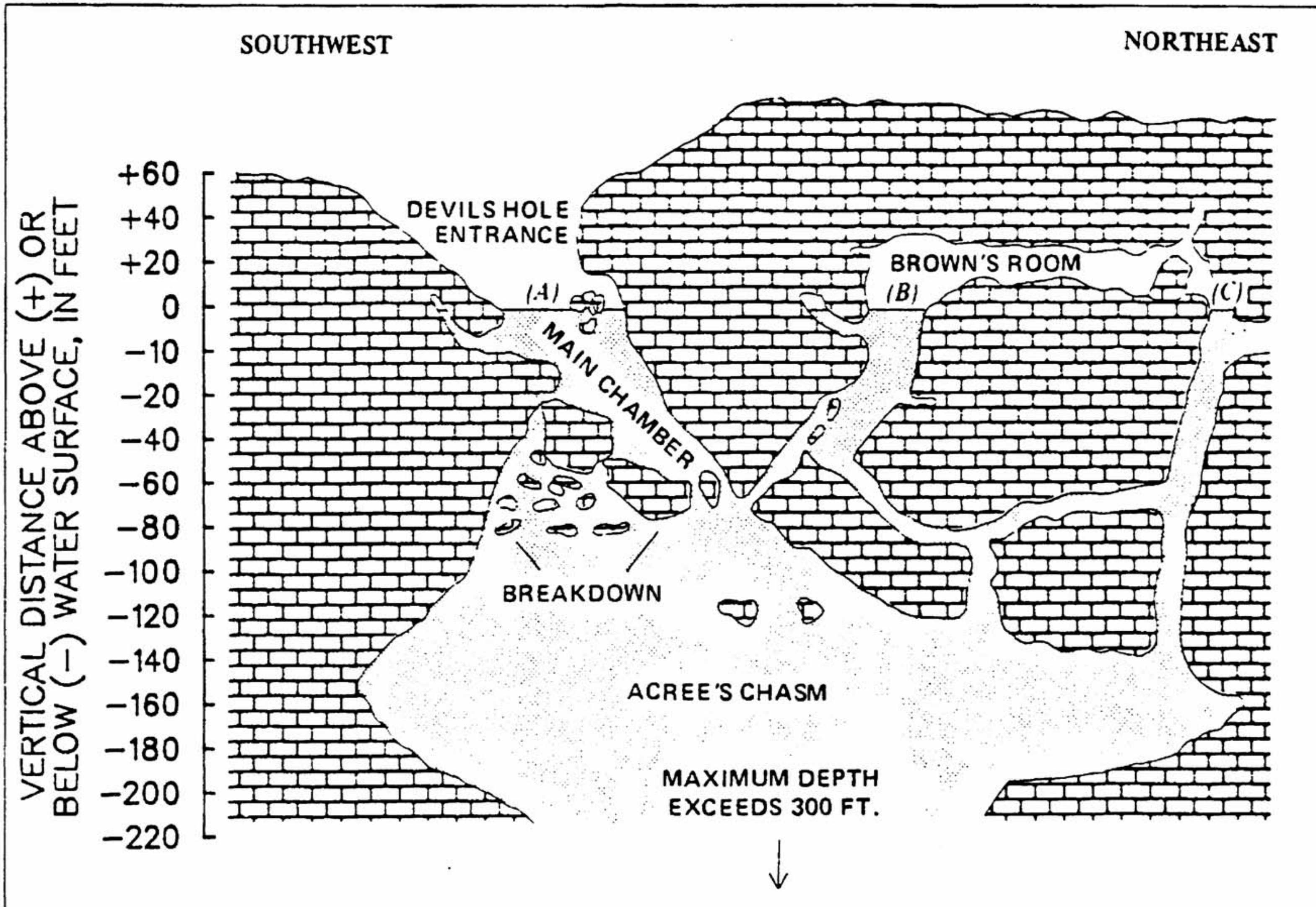
The Connecticut River Experiment



Devils Hole Pupfish (*Cyprinodon diabolis*)

An Ongoing Lesson in Conservation Biology
with thanks to Andrew Martin (U Colorado)
and John Wullschleger (NPS Water Resources)


80
Great Basin NP
Death Valley NP
Devils Hole
15
Las Vegas
Lake Mead
NRA
Map by Marie Denn
NPS - PWR


SOUTHWEST
NORTHEAST
VERTICAL DISTANCE ABOVE (+) OR BELOW (−) WATER SURFACE, IN FEET
+60
+40
+20
0
−10
−20
−40
−60
−80
−100
−120
−140
−160
−180
−200
−220
DEVILS HOLE ENTRANCE
(A)
MAIN CHAMBER
BROWN'S ROOM
(B)
(C)
BREAKDOWN
ACREE'S CHASM
MAXIMUM DEPTH EXCEEDS 300 FT.

Devils Hole Abbreviated Chronology

1952 Devils Hole is protected as a 40 acre disjunct unit of Death Valley National Monument.

1967 Devils Hole pupfish is listed as an endangered species.

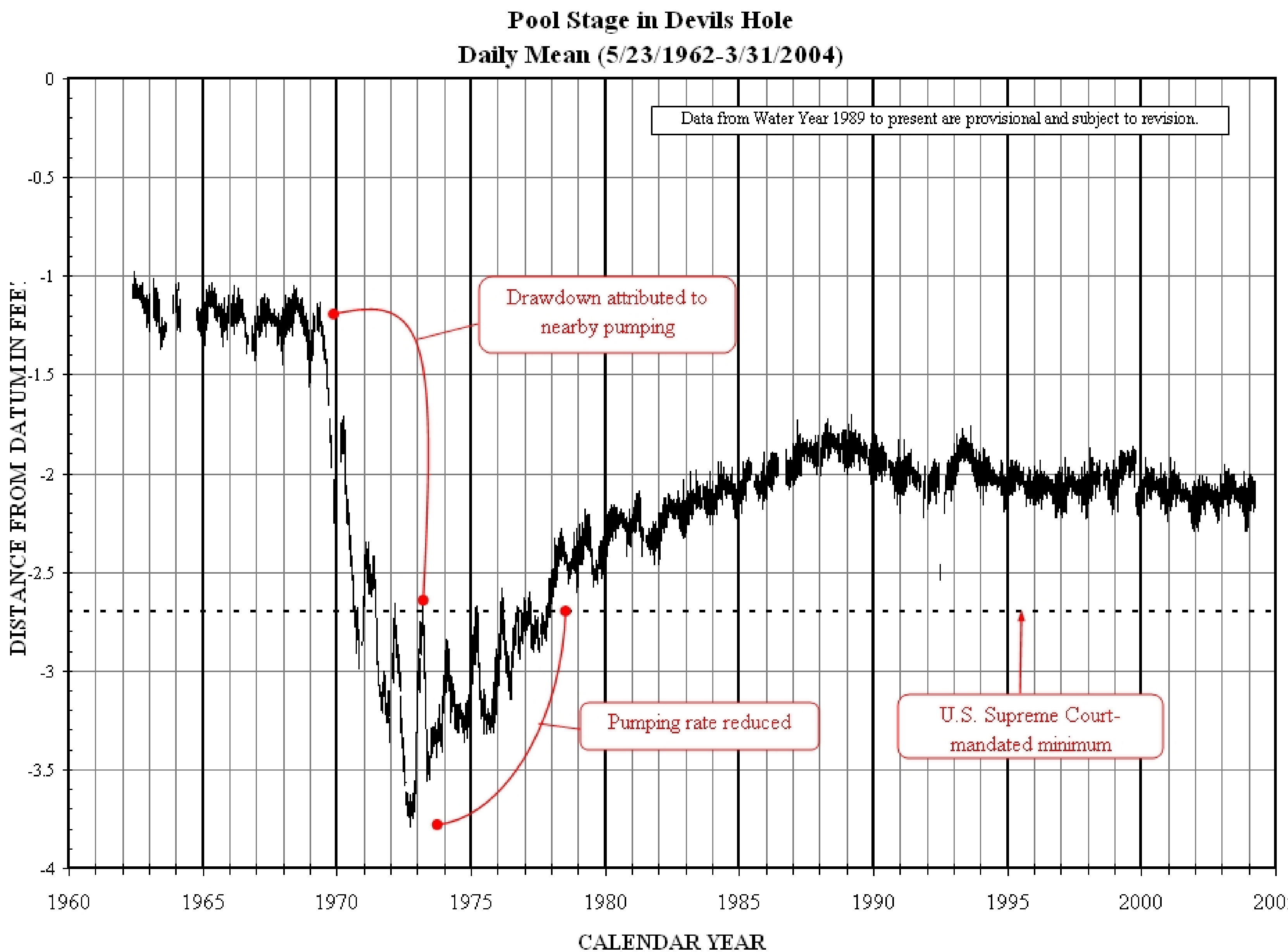
1976 Supreme Court concludes that when NPS acquired Devils Hole the federal government implicitly reserved sufficient water to protect the pupfish and its habitat.

A lower court then established minimum water level.

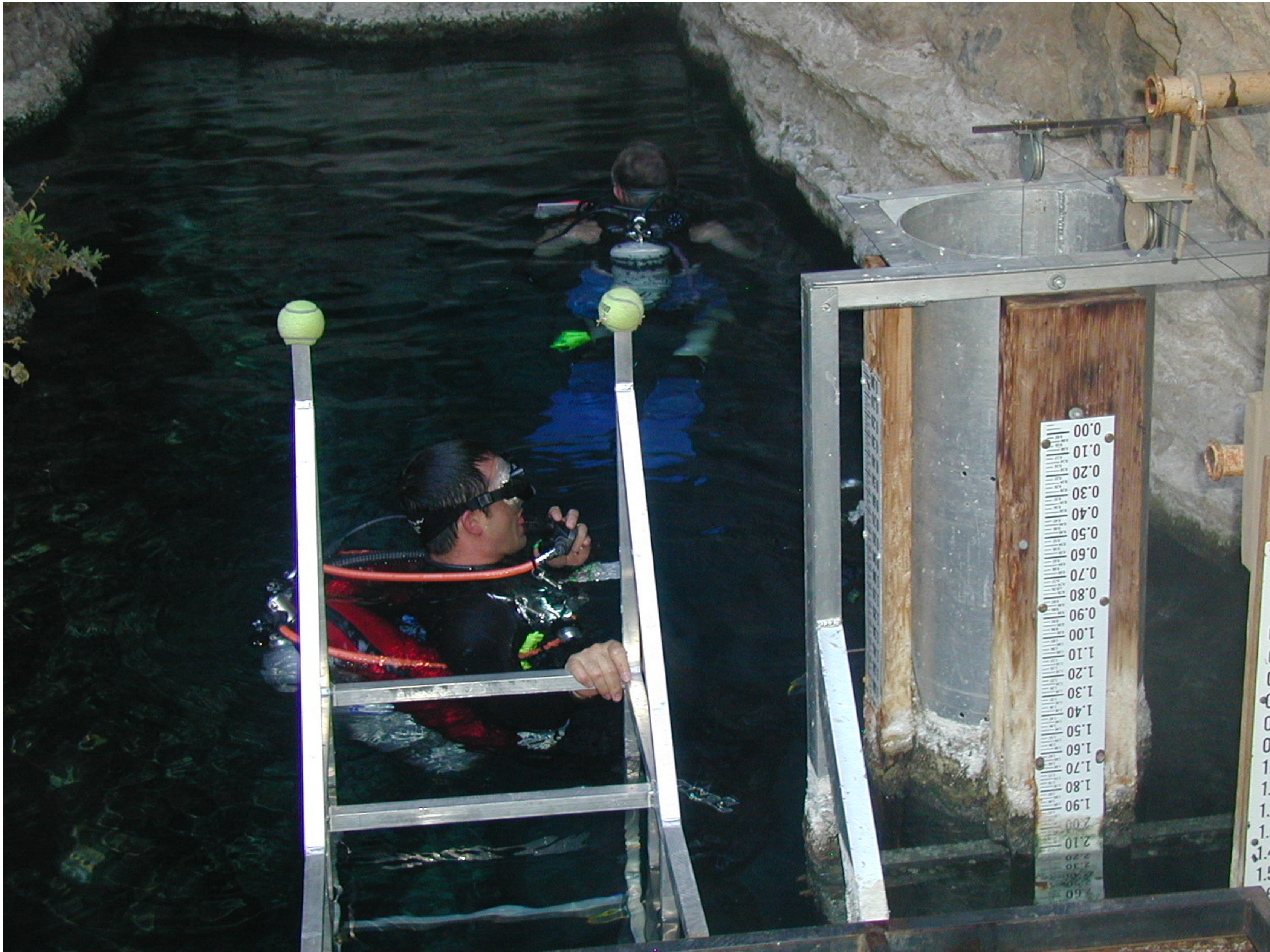
1984 Ash Meadows National Wildlife Refuge is established, in part to prevent groundwater pumping near to Devils Hole.

1994 Death Valley and Devils Hole become a National Park.

2004 Flash flood kills at least 80 adult pupfish in Devils Hole.



Pool Stage in Devils Hole
Daily Mean (5/23/1962-3/31/2004)
Data from Water Year 1989 to present are provisional and subject to revision.
Drawdown attributed to nearby pumping
Pumping rate reduced
U.S. Supreme Court-mandated minimum
DISTANCE FROM DATUM IN FEET
CALENDAR YEAR
0
-0.5
-1
-1.5
-2
-2.5
-3
-3.5
-4
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005


0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
1.10
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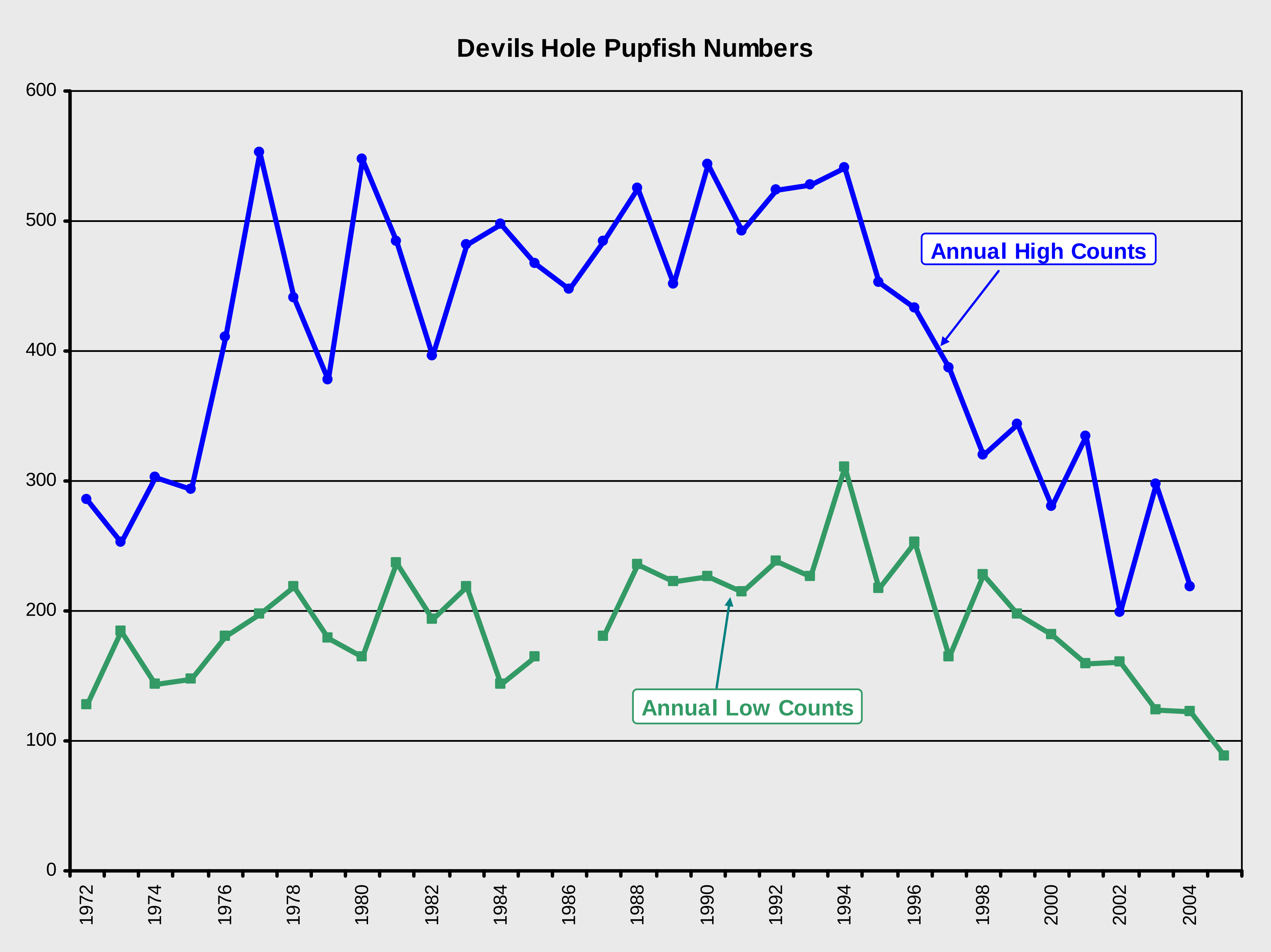
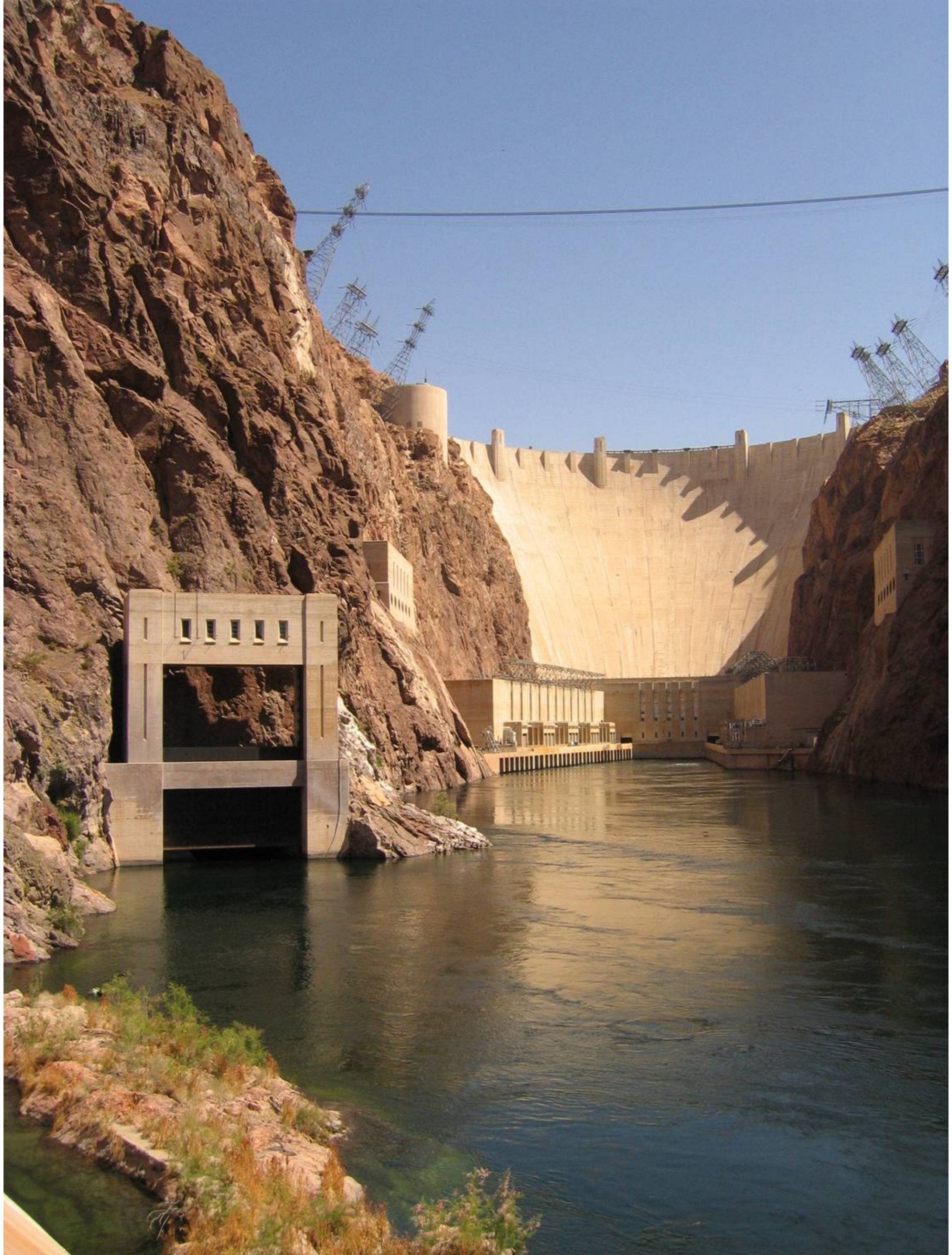
1.30
1.40
1.50
1.60
1.70
1.80
1.90
2.00
2.10


Devils Hole Pupfish Numbers
600
500
400
300
200
100
0
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
Annual High Counts
Annual Low Counts


Stevens


DEATH VALLEY



Devils Hole Pupfish Populations

Devils Hole (DH) Death Valley NP	84 mature
Point of Rocks (PoR) FWS Refuge	180 (likely hybrids with *C. nevadensis*)
Hoover Dam (HD) BOR Refuge	50 mature

Estimates of population genetic differentiation using R_{ST} above the diagonal and F_{ST} below the diagonal

	DH	HD	PoR '98	PoR '05
DH		0.108*	0	0.593***
HD	0.072***		0.032	0.365***
PoR 1998	0.007	0.044**		0.513***
PoR 2005	0.179**	0.221**	0.182**	

Possible Recovery Actions

1. Remove some Devils Hole fish to Hoover Dam and expand population.

2. Remove some Devils Hole fish to Point of Rocks, and backcross with current stock.

3. Add fish to Devils Hole from either refuge.

4. Add no fish and monitor Devils Hole.

What do you think?

Captive Propagation Program for the Key Largo Woodrat (*Neotoma floridana smalli*)

- One of 5 named subspecies of the Eastern woodrat
- Classified as a federally endangered species in 1984 due to concerns over habitat loss and the impact of commercial development
- Nocturnal herbivore, feeding on the buds, leaves, and fruit of many plant species
- "Females can have up to two litters a year, consisting of one to four young with an average of two"

Subspecies Justification

160 miles

Virtually no hardwood hammock between localities

Morphological differences

Molecular taxonomy unknown

Population Decline

- During the late 70's and early 80's stick nests were abundant in North Key Largo
- In 1986 Humphrey estimated the KLWR population to be ~6,500 individuals.
- Large decline appeared to occur during the late 80's and early 90's when there was no trapping occurring

Potential Threats:

Habitat Loss and degradation

Habitat management

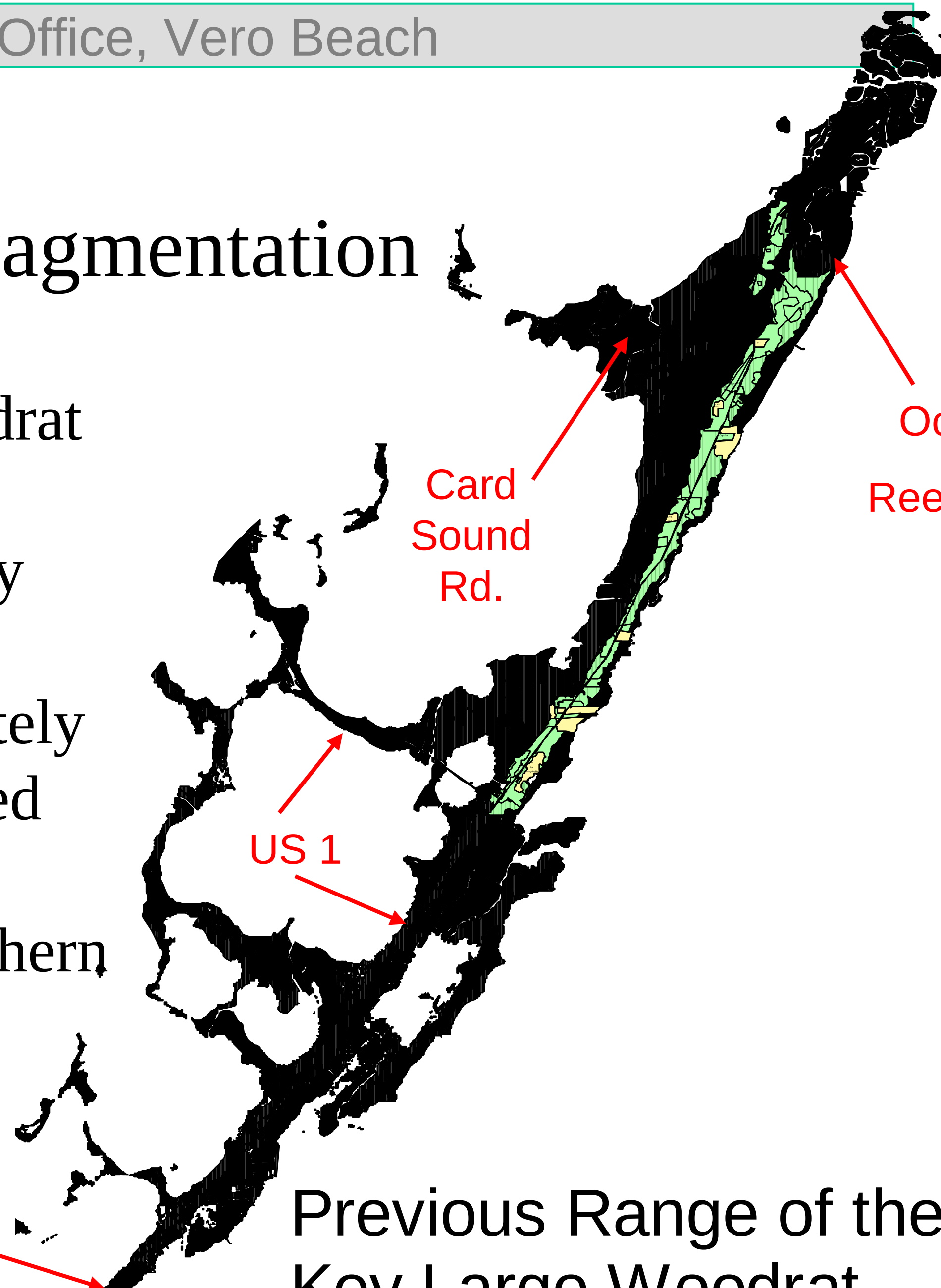
Disease

Introduced predators and competitors

Interactions of factors and demographic effects

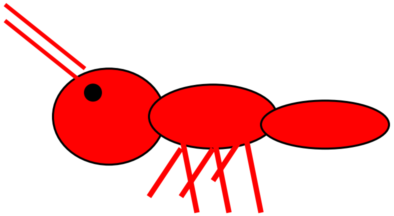
Habitat Loss and Fragmentation

More then 47% of woodrat habitat has been lost to development, today Key Largo woodrats are restricted to approximately 850 hectares of protected tropical hardwood hammock forest in northern Key Largo



Previous Range of the Key Largo Woodrat

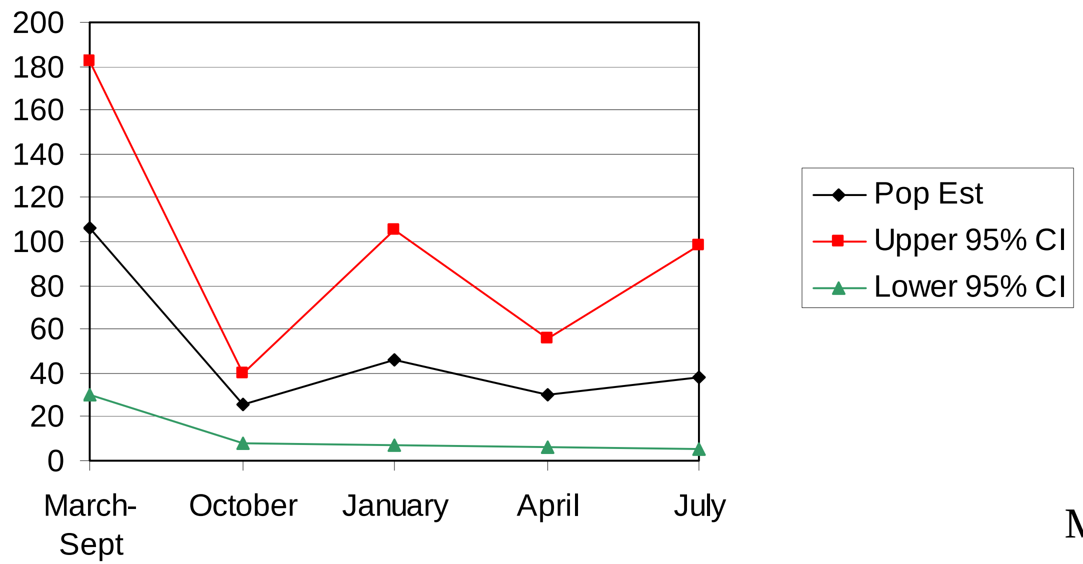
Predators and Competitors



Current Population Estimates

By 1995 stick nests had all but disappeared from North Key Largo

The KLWR population was estimated at 106 (30-182) in 2002, an October 2004 report estimated the current population at 40 (5-104).

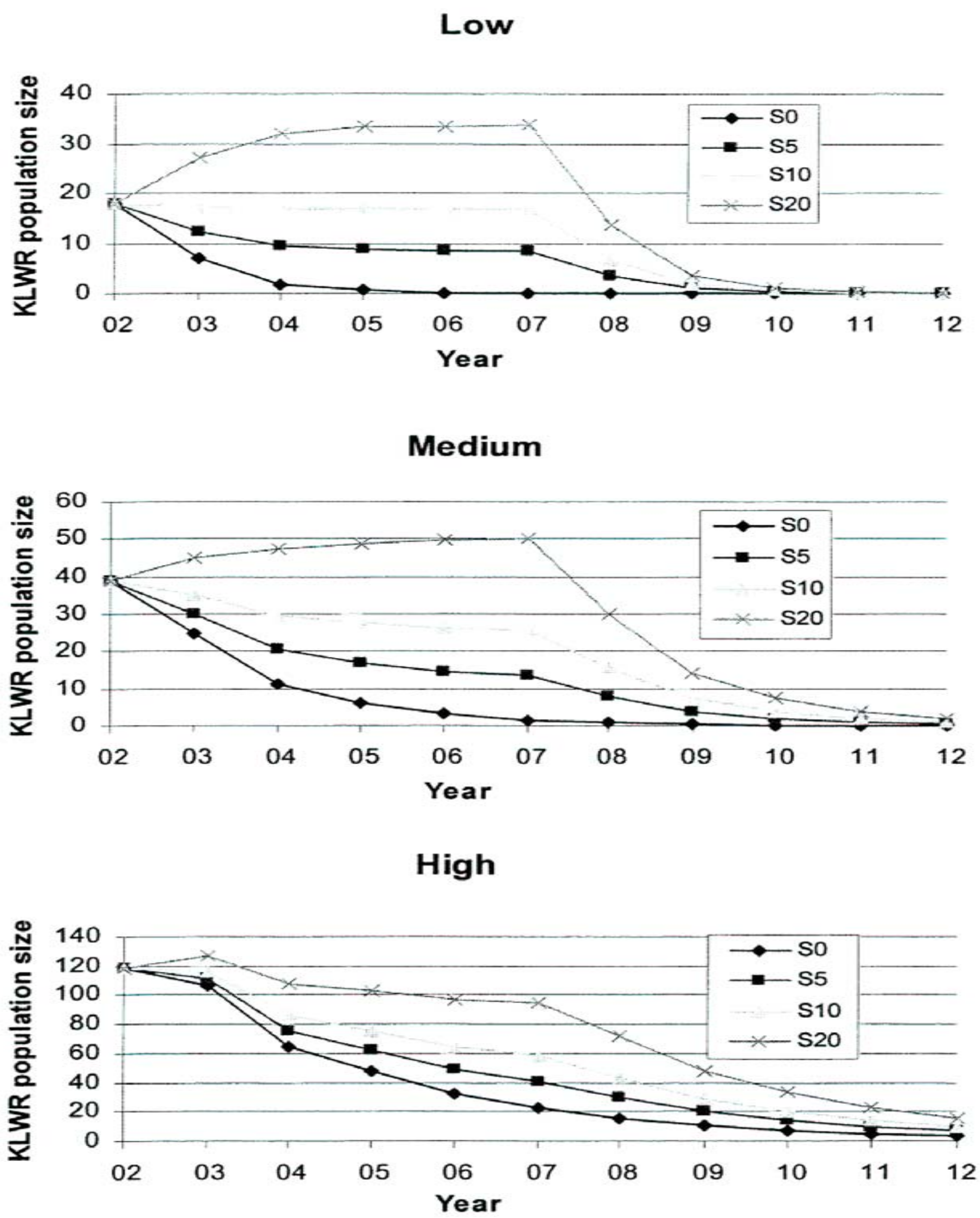


McCleery et al 2004

2003 PVA (McCleery et al 2004)

Predicts a 70 to 98 % risk of extinction in 10 years regardless of “best case scenario” or “worst case scenario” parameters

Introduction of 20 females annually for 5 years may prevent extinction, although once introductions are stopped the PVA continues to predict extinction



In April 2002, we initiated an experimental captive propagation program and began developing a captive propagation and reintroduction plan in accordance with Service policy.

HERBERT

SOPHIE

Captive Propagation and Reintroduction Plan

Objectives:

Prevent the extinction of KLWRs in the wild by maintaining the population through augmentation with captive-born woodrats

Maintain present levels of genetic diversity (i.e. fitness) and heterozygosity

Captive Propagation and Reintroduction Plan

Objectives:

Maximize the conservation of genetic diversity in both the wild and captive populations by developing appropriate measures to safeguard and increase diversity

Maintain refugia populations in captivity until causes of the current decline are understood and addressed

Maintain refugia populations in captivity in case of catastrophic events

After proving husbandry techniques we brought two more woodrats into captivity and began attempting to breed woodrats.

BILL

FELICIA

Woodrats are territorial and will fight to the point of causing serious injury, therefore all woodrats are housed separately and all breeding attempts are observed by zoo staff

SUCCESS!!

5/10/03 Sophie and Bill became the proud parents of two female pups

5/23/03 Felicia and Bert became the proud parents of a single male pup

ONLY after demonstrating breeding success did the RO authorize us to fully implement the Plan and bring in 12 woodrats from the wild

With breeding success came the need for

Genetics-based Captive Breeding Management

In order to meet the objectives of the Captive Propagation and Reintroduction Plan all woodrats are genotyped at microsatellite DNA loci to establish relatedness to other captive individuals. Pairwise genetic relatedness (based on multilocus genotypes) determines potential matings. The ultimate objective is to avoid inbreeding depression while maximizing genetic diversity and heterozygosity.

Genetic Analysis

- Closest known relative is the Eastern woodrat (*Neotoma floridana floridana*)
- This non-listed subspecies served as a “surrogate species” for training Service and Commission biologists to take blood samples and insert microchip identification tags
- No phylogenetic analyses comparing the two subspecies have been reported (research currently underway)
- Compare genetic diversity within and between subspecies to place observed levels of *N. f. smalli* genetic diversity into proper phylogenetic perspective.

Methods

Trapping performed by USFWS Ecological Services

Blood taken and preserved on FTA cards; tail tips also placed in ethanol

Fecal samples placed on FTA cards and in alcohol

Genotyping performed by USGS

Microsatellite DNA markers developed for congeneric species (Allegheny woodrat)

Nine markers currently in use; others being developed

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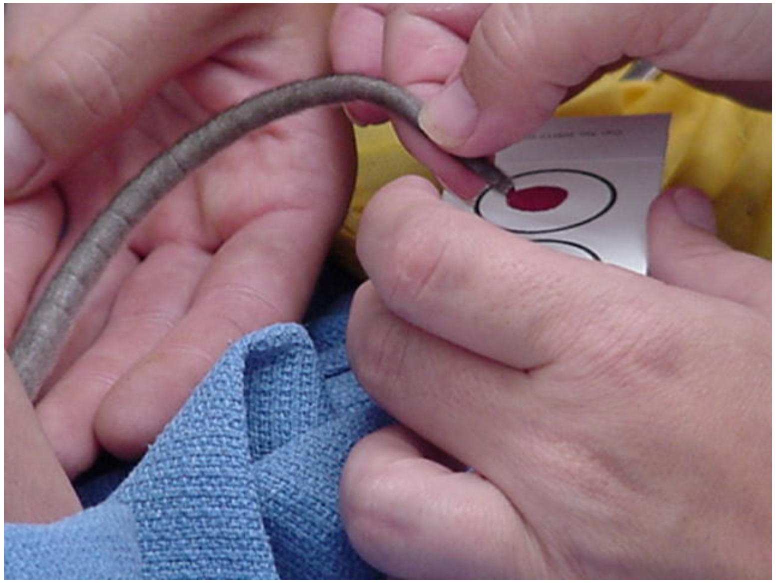
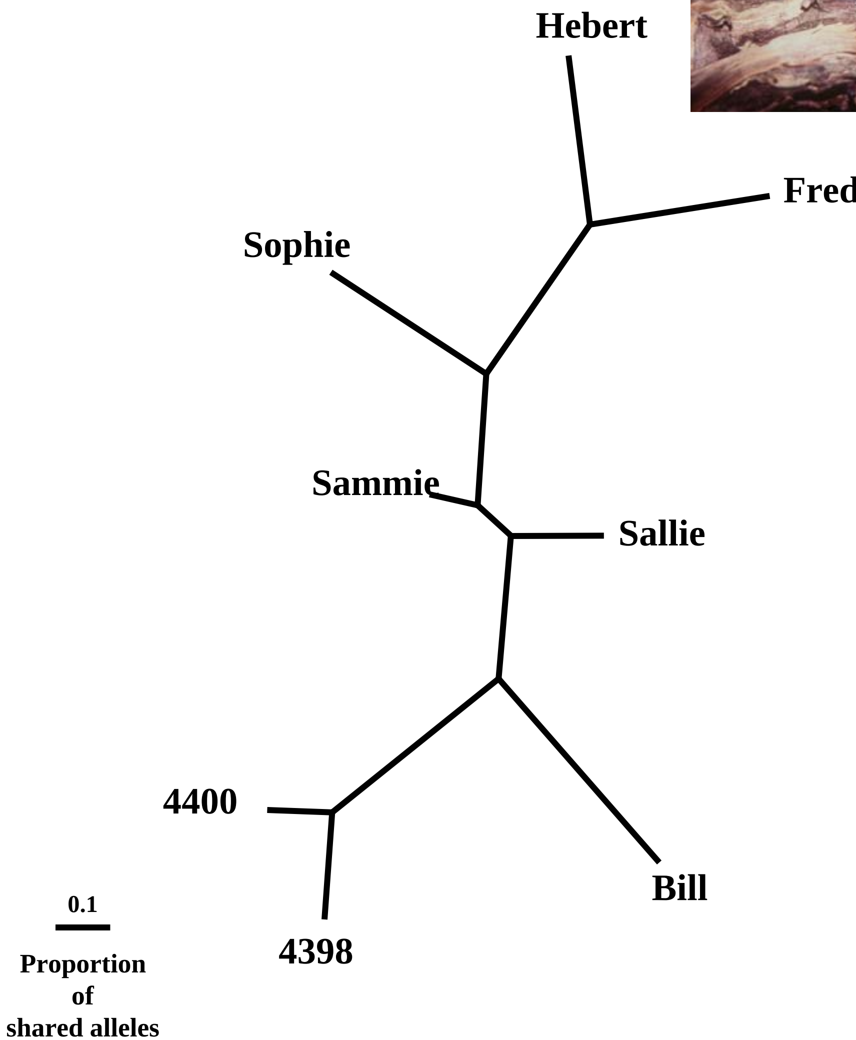
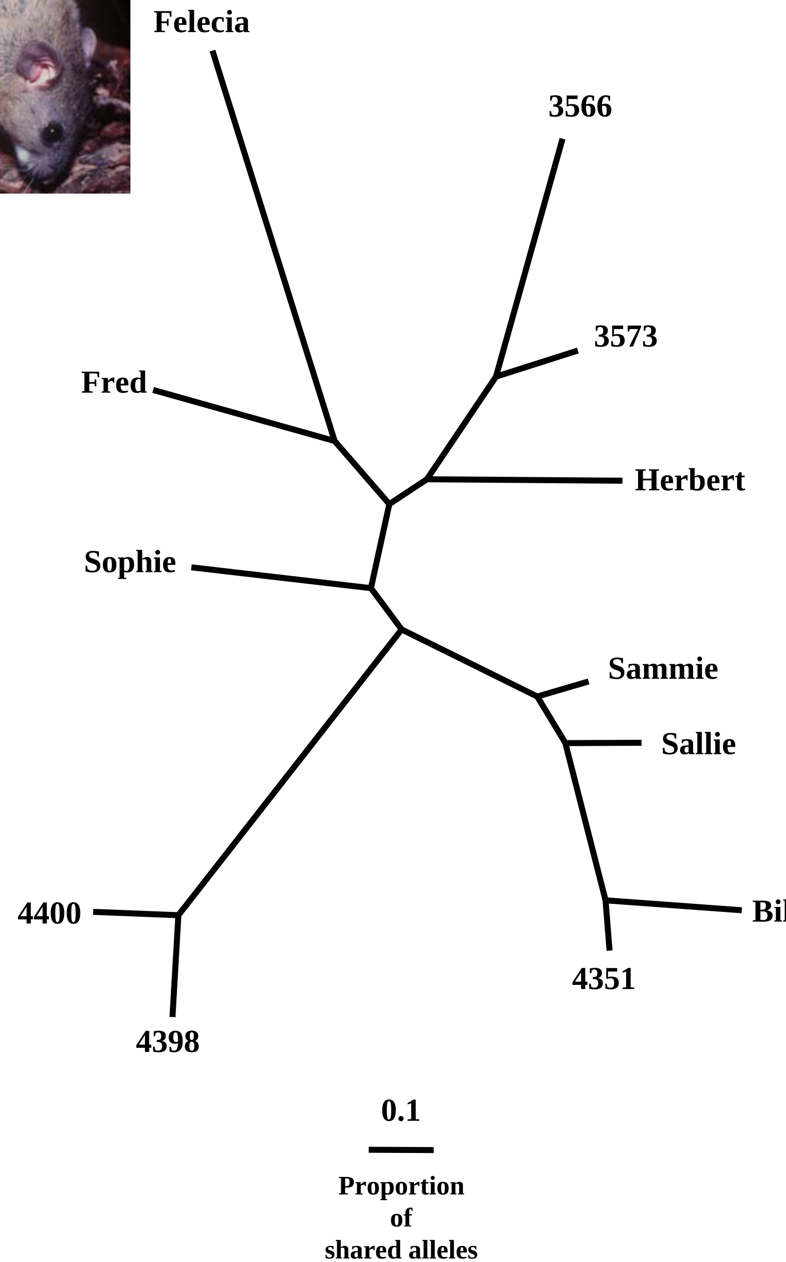


8 animal tree

12 animal tree





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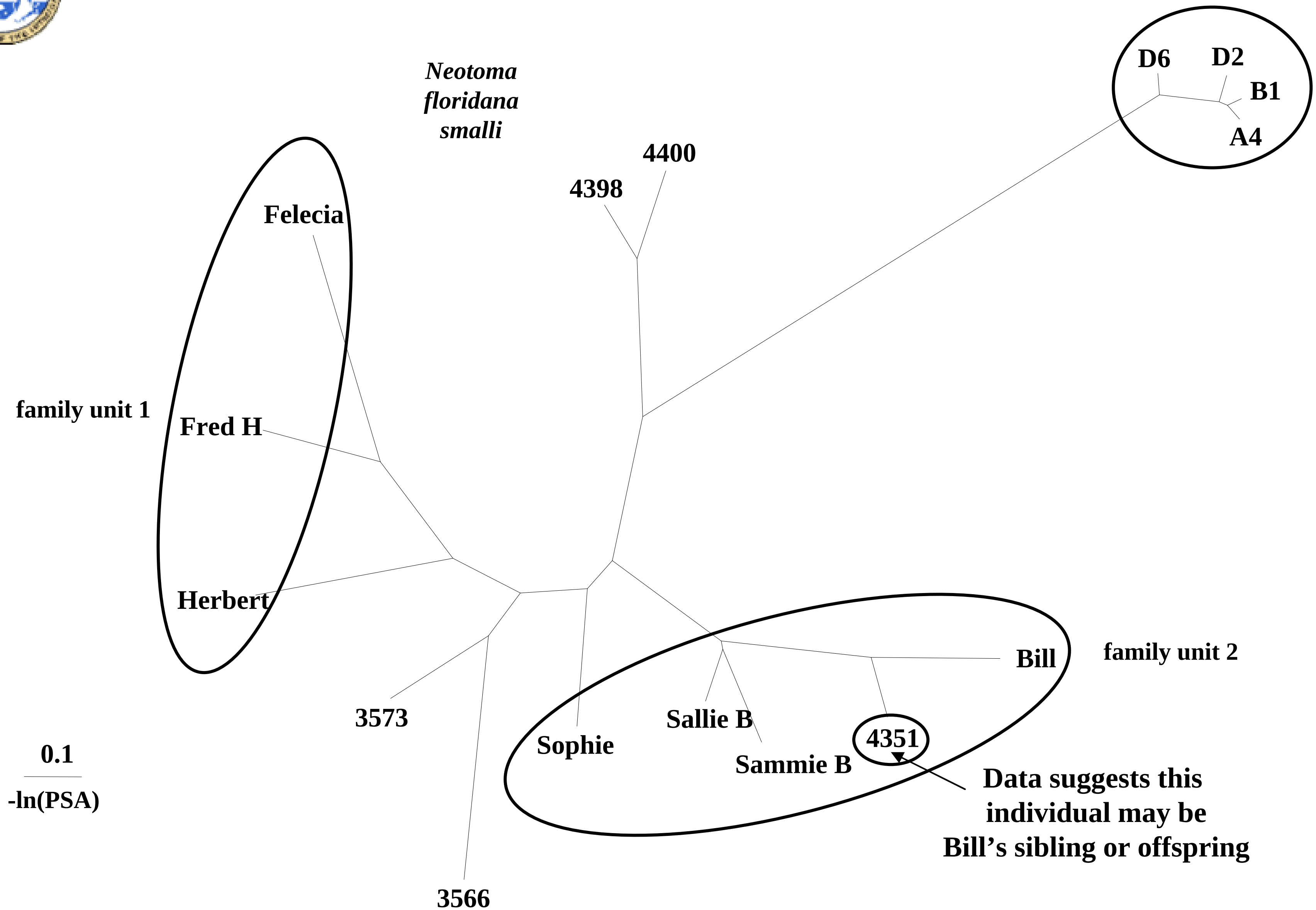
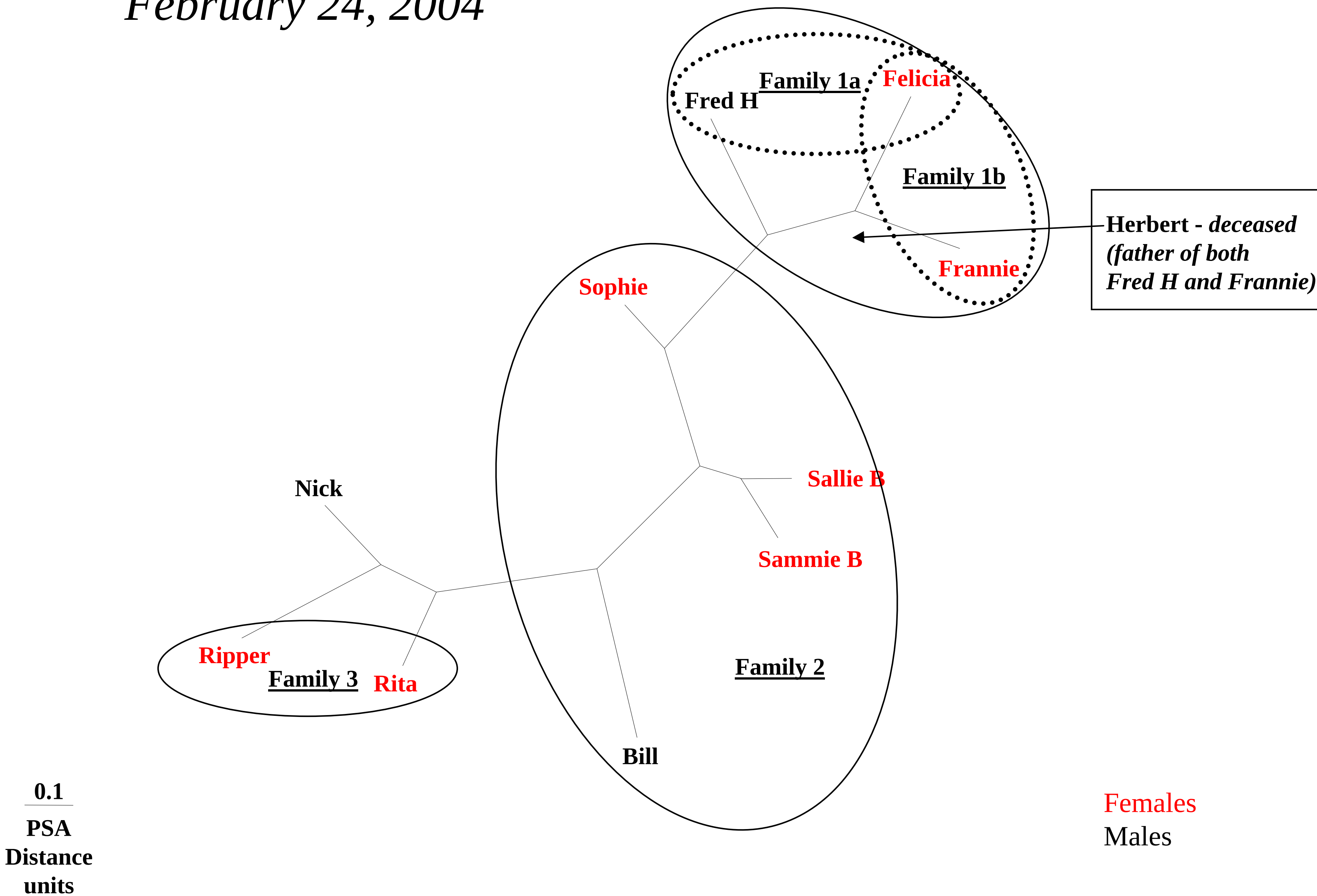


Unrooted neighbor-joining tree

Captive *Neotoma floridana smalli*
February 24, 2004



Animal 1	Animal 2	PSA	Relationship
Molly	Jamie	0.251	siblings
Ripper	Nick	0.492	unknown
Rita	Ripper	0.492	mother-daughter
Bert	Sam	0.588	father-son
Bert	Sophie	0.588	related?
Bill	Jamie	0.588	father-daughter
Bill	Molly	0.588	father-daughter
Rita	Nick	0.588	related?
Sam	Felecia	0.588	mother-son
Sophie	Jamie	0.588	mother-daughter
Sophie	Molly	0.588	mother-daughter
Sophie	Sam	0.693	related?
Bill	Rita	0.811	related?
Bert	Jamie	0.944	unknown
Bert	Molly	0.944	unknown
Bill	Nick	0.944	unknown
Molly	Felecia	0.944	unknown
Sophie	Felecia	0.944	unknown
Sophie	Rita	0.944	unknown
Bert	Felecia	1.099	paired family 1
Bert	Nick	1.099	unknown
Sam	Jamie	1.099	unknown
Sophie	Nick	1.099	unknown
Sophie	Ripper	1.099	unknown
Bert	Rita	1.281	unknown
Bill	Ripper	1.281	unknown
Bill	Sophie	1.281	paired family 2
Jamie	Felecia	1.281	unknown
Jamie	Rita	1.281	unknown
Molly	Nick	1.281	unknown
Molly	Rita	1.281	unknown
Sam	Molly	1.281	unknown
Sam	Nick	1.281	unknown
Sam	Rita	1.281	unknown
Bert	Ripper	1.504	unknown
Bill	Bert	1.504	unknown
Jamie	Nick	1.504	unknown
Molly	Ripper	1.504	unknown
Sam	Ripper	1.504	unknown
Bill	Felecia	1.792	unknown
Bill	Sam	1.792	unknown
Felecia	Nick	1.792	unknown
Felecia	Ripper	1.792	unknown
Jamie	Ripper	1.792	unknown
Rita	Felecia	1.792	unknown

Scenario A

Site 1	Site 2
Nick	Bill
Sam	Bert
Jamie	Rita
Molly	Felecia
Sophie	Ripper
	[Fran]

	Site 1	PSA
Sophie	Nick	1.099
Molly	Nick	1.281
Jamie	Nick	1.504
Sophie	Sam	0.693
Sam	Jamie	1.099
Sam	Molly	1.281
	Mean	***1.160***
	Std	***0.273***

	Site 2	PSA
Bill	Rita	0.811
Bill	Felecia	1.792
Bill	Ripper	1.281
Bert	Felecia	1.099
Bert	Rita	1.281
Bert	Ripper	1.504
	Mean	***1.295***
	Std	***0.336***

Scenario B

Site 1	Site 2
Nick	Bert
Bill	Sam
Felecia	Rita
Sophie	Ripper
[Fran]	Jamie
	Molly

	Site 1	PSA
Felecia	Nick	1.792
Sophie	Nick	1.099
Bill	Felecia	1.792
Bill	Sophie	1.281
	Mean	***1.491***
	Std	***0.355***

	Site 2	PSA
Bert	Rita	1.281
Bert	Ripper	1.504
Bert	Jamie	0.944
Bert	Molly	0.944
Sam	Rita	1.281
Sam	Ripper	1.504
Sam	Jamie	1.099
Sam	Molly	1.281
	Mean	***1.230***
	Std	***0.220***

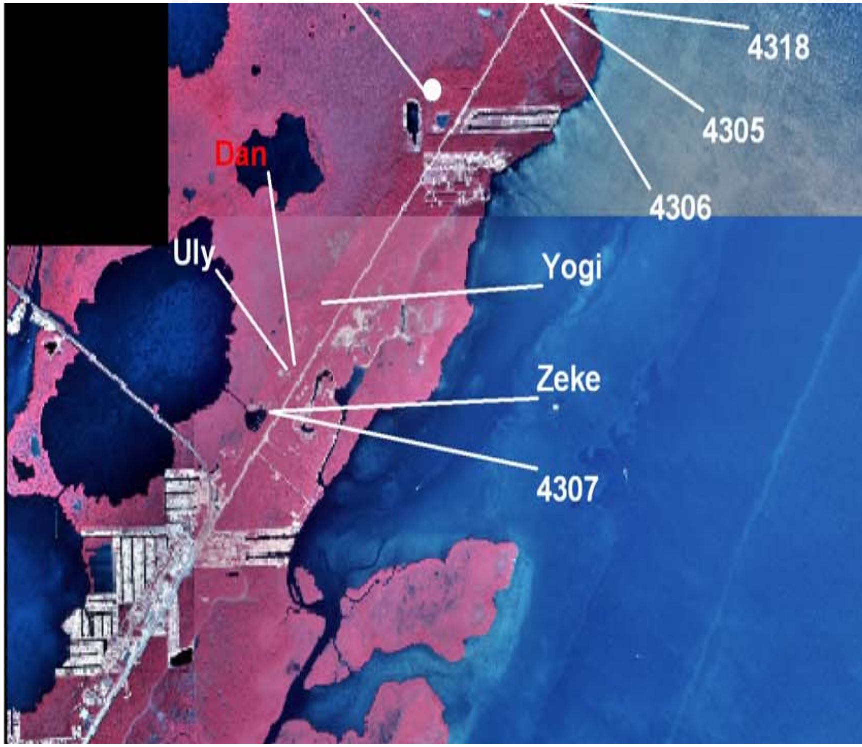
Scenario C

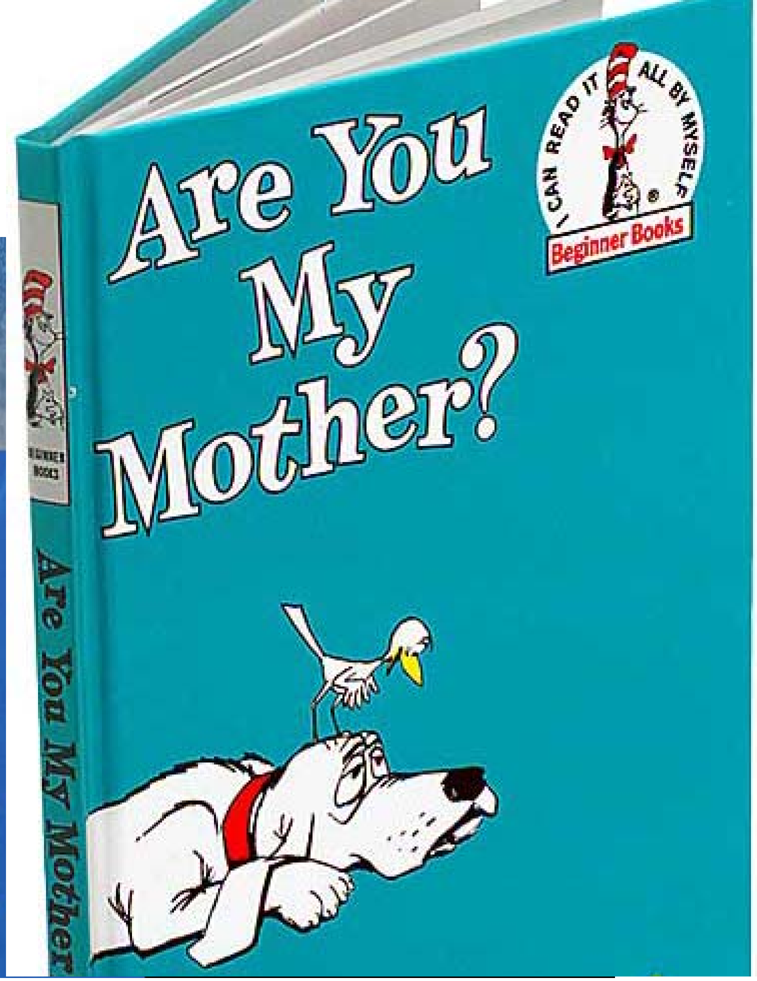
Site 1	Site 2
Nick	Bill
Bert	Sam
Molly	Rita
Jamie	Ripper
Felecia	Sophie
	[Fran]

	Site 1	PSA
Molly	Nick	1.281
Jamie	Nick	1.504
Felecia	Nick	1.792
Bert	Molly	0.944
Bert	Jamie	0.944
Bert	Felecia	1.099
	Mean	***1.261***
	Std	***0.337***

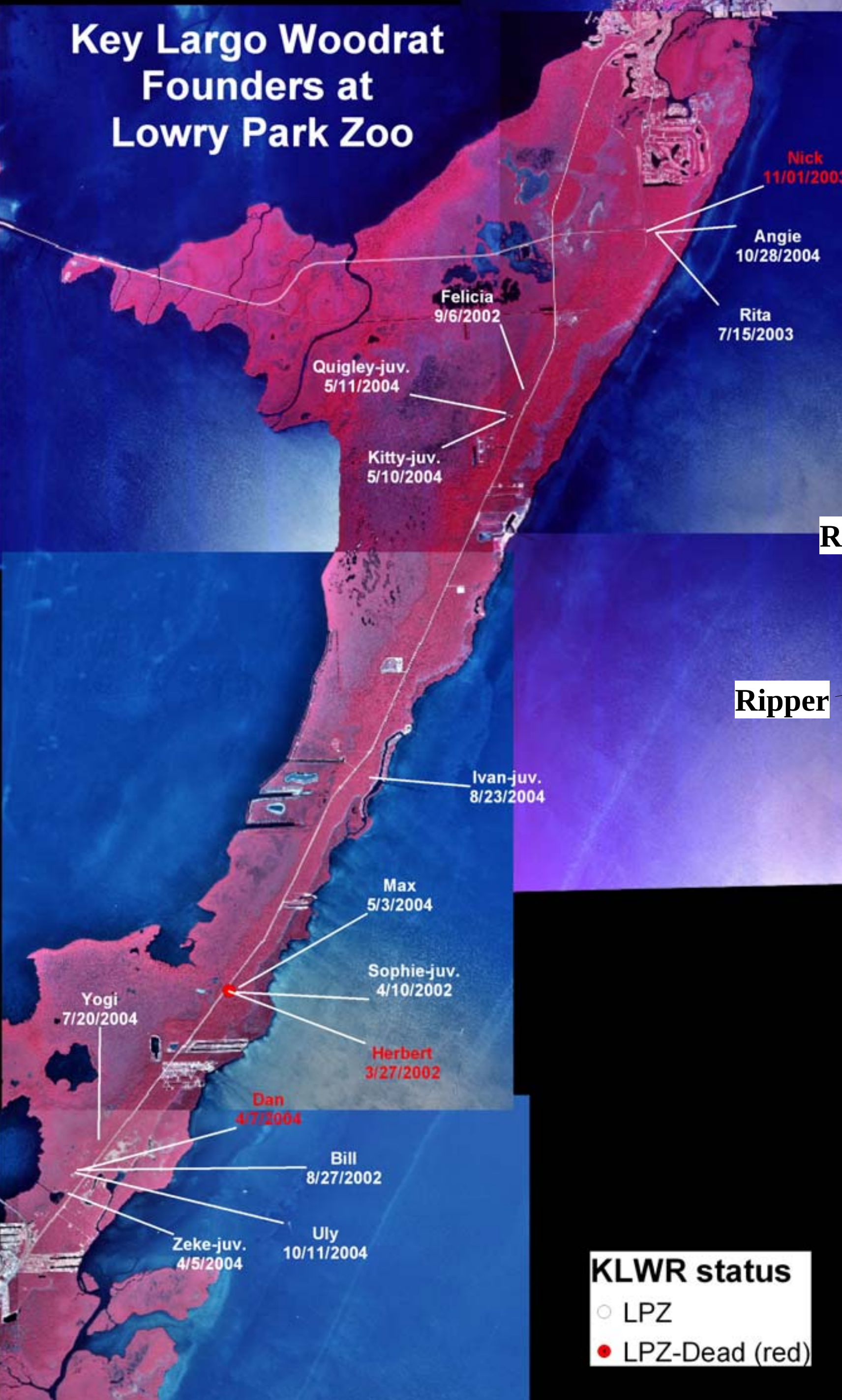
	Site 2	PSA
Bill	Rita	0.811
Bill	Ripper	1.281
Bill	Sophie	1.281
Sam	Rita	1.281
Sam	Ripper	1.504
Sophie	Sam	0.693
	Mean	***1.142***
	Std	***0.316***

Parentage Question

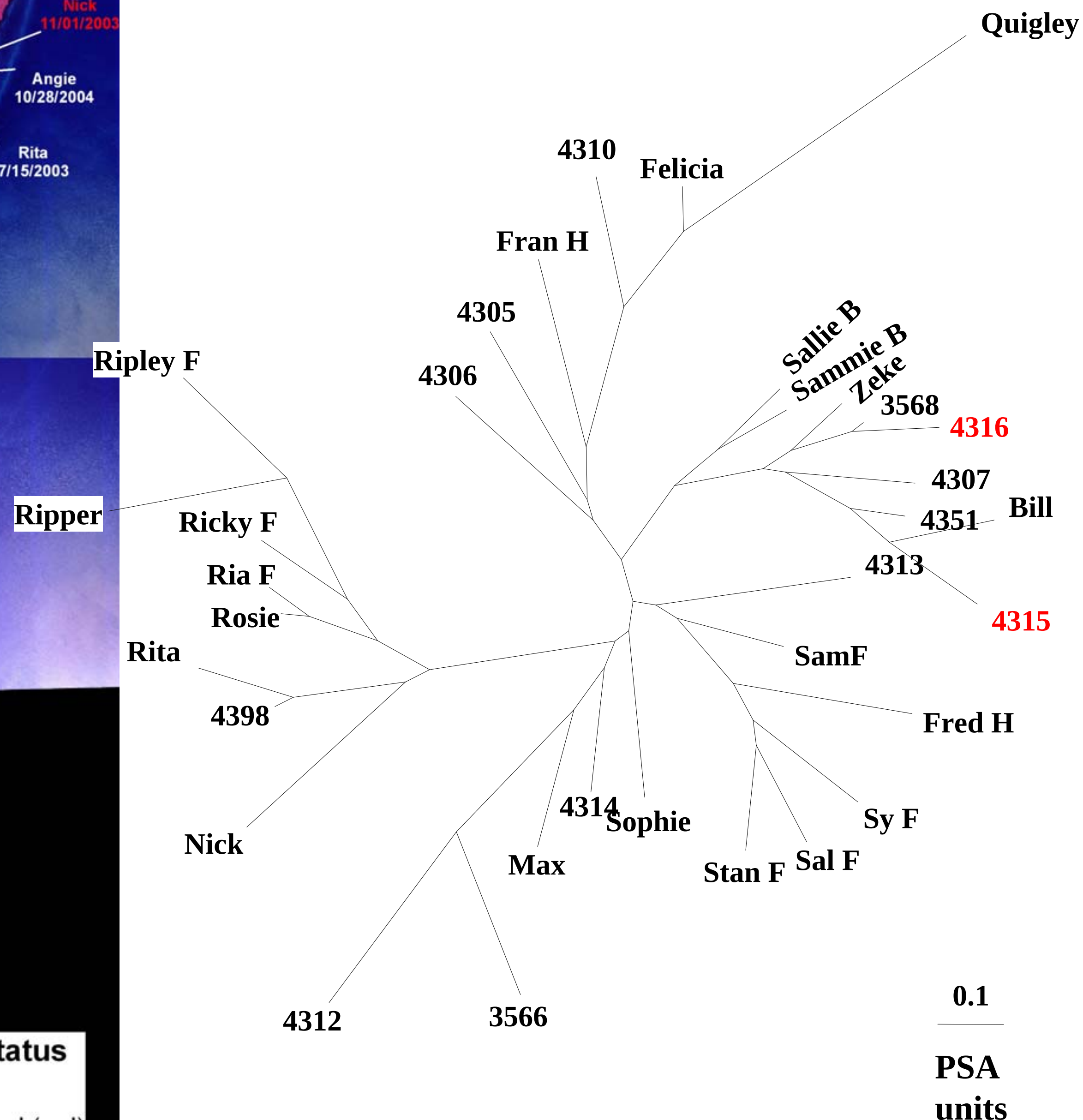




Woodrat	Nma1	Nma1		Nma4	Nma4 2		Nma5	Nma5		Nma8	Nma8		Nma10	Nma10		Nma11	Nma11		Nma14	Nma14		NmaD21	NmaD21		NmaD138	NmaD138	
4307	321	321		165	171		231	243		132	138		213	225		164	166		161	163		155	155		293	297	Mom - ?
Zeke	315	321		159	165		231	231		132	138		213	225		164	164		161	161		151	155		293	297	
Dan	301	321		153	159		243	243		134	138		209	225		162	164		163	167		151	155		293	293	Dad - no



Most Recent Family Tree



Controlled Propagation Prospects and Obstacles

Successful Breeding – 14 pups, 6 single pup births and 4 “twin” births; captive-born individuals have been successfully mated both to each other and to wild-caught individuals

Genetic analysis – high level of diversity

Have brought in all 12 wild-caught individuals allowed by the Plan (Total 13 male, 13 female)

KLWRs will be split into 2 captive populations, endocrinology lab

Controlled Propagation Prospects and Obstacles

Captive aggression increasing – loss of one wild-caught male

Causes of decline yet to be fully identified or addressed

Hesitant to release captive animals until we understand and address the causes and issues behind the decline of the wild population

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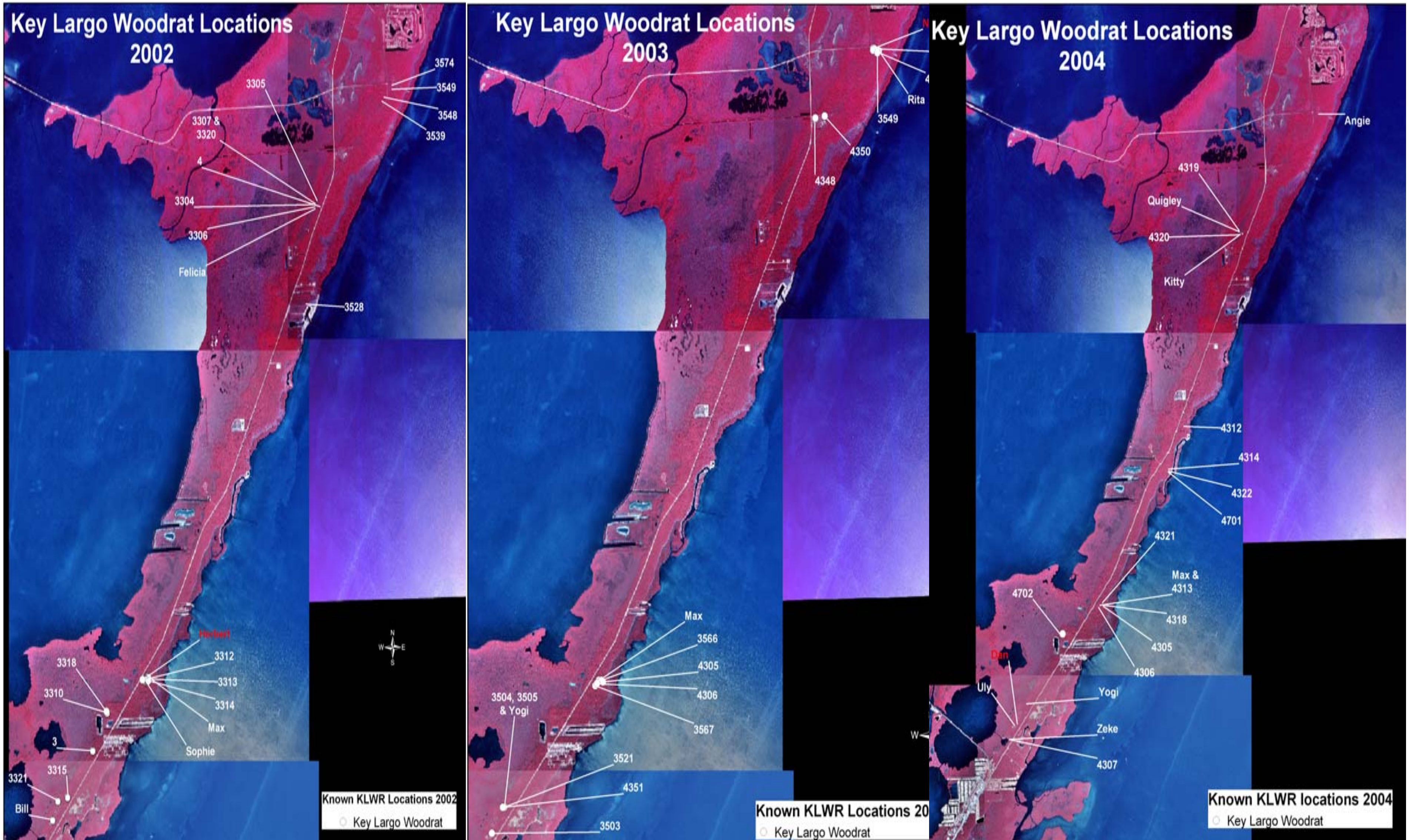
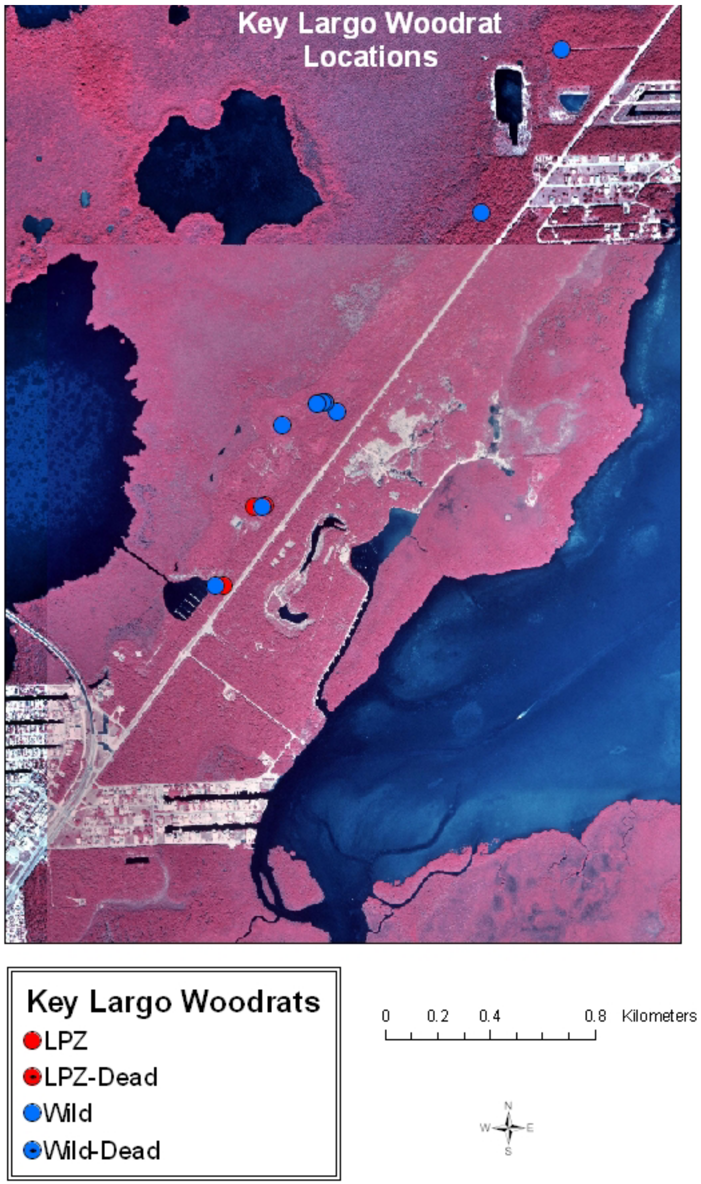
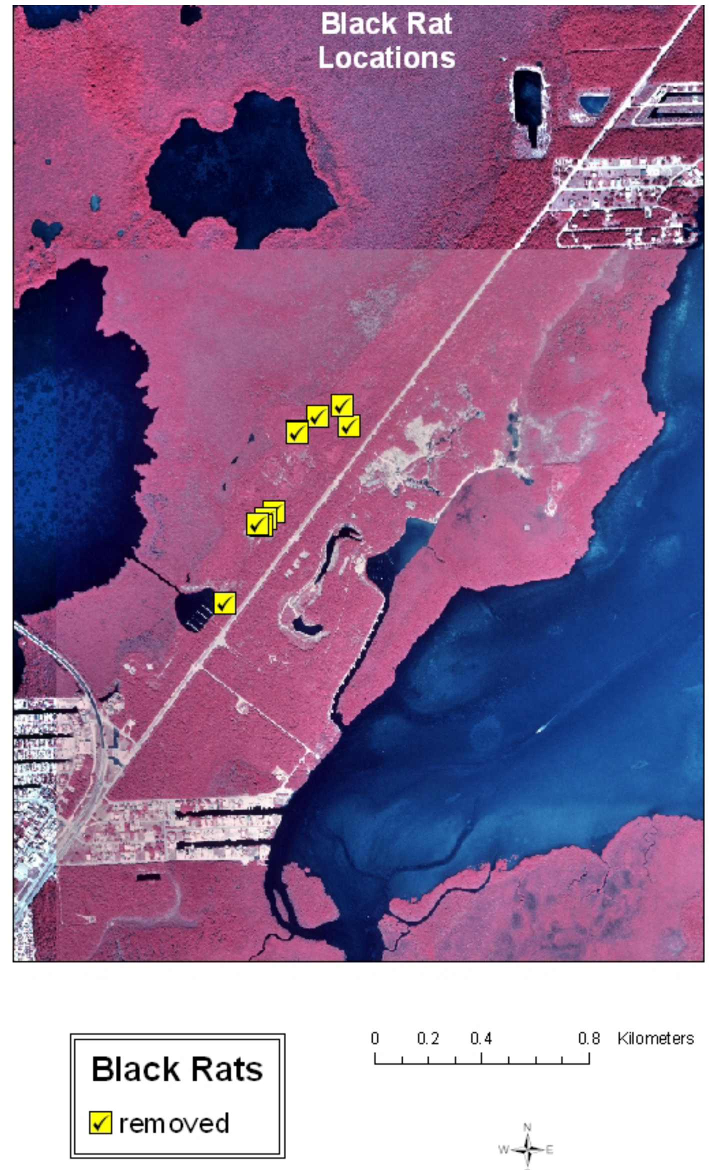


Woodrat vs. Black Rat Locations 2002-2004





Recent Success in the Wild

2002 - 13 “new” woodrats captured

2003 - 14 “new” woodrats captured

2004 – 20 “new” woodrats captured, 10 of which were captured in October and November

First stick nest identified last month from an area where more then 30 raccoons have been removed!

Partners:

USFWS

USGS

Florida Fish and Wildlife Conservation Commission

Florida Department of Environmental Protection

Lowry Park Zoo

Texas A&M University

University of Georgia

Copyrighted zoological facility outside of Orlando